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

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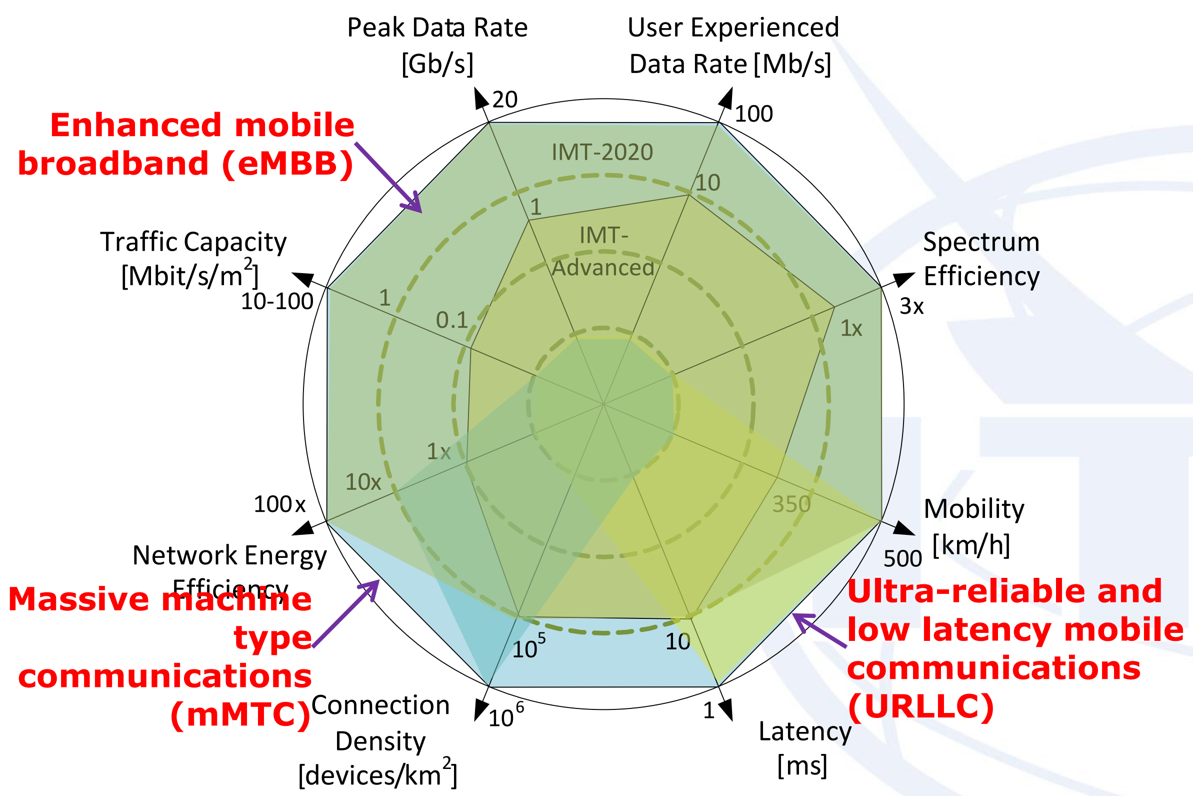
Outline

- 5G/IMT2020 as key driver for industrial and societal changes
- Distinguishing features - and high level requirements - of 5G/IMT-2020 networks

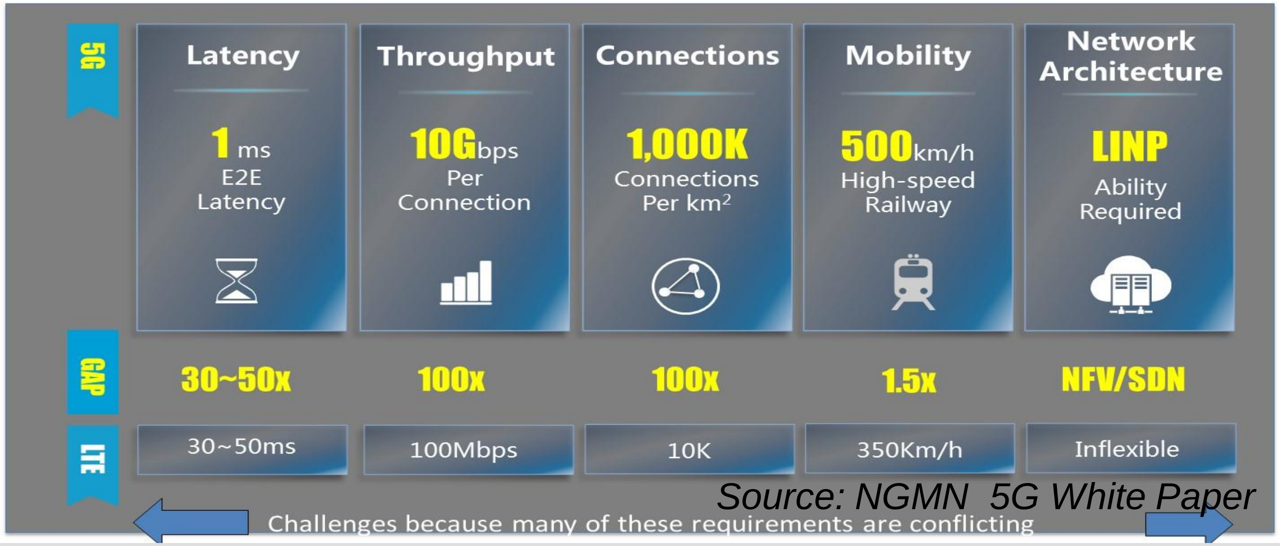
NOTE 1 – Only a limited set of topics is addressed (see for example [ITU-T Y.3101] for a wider perspective)

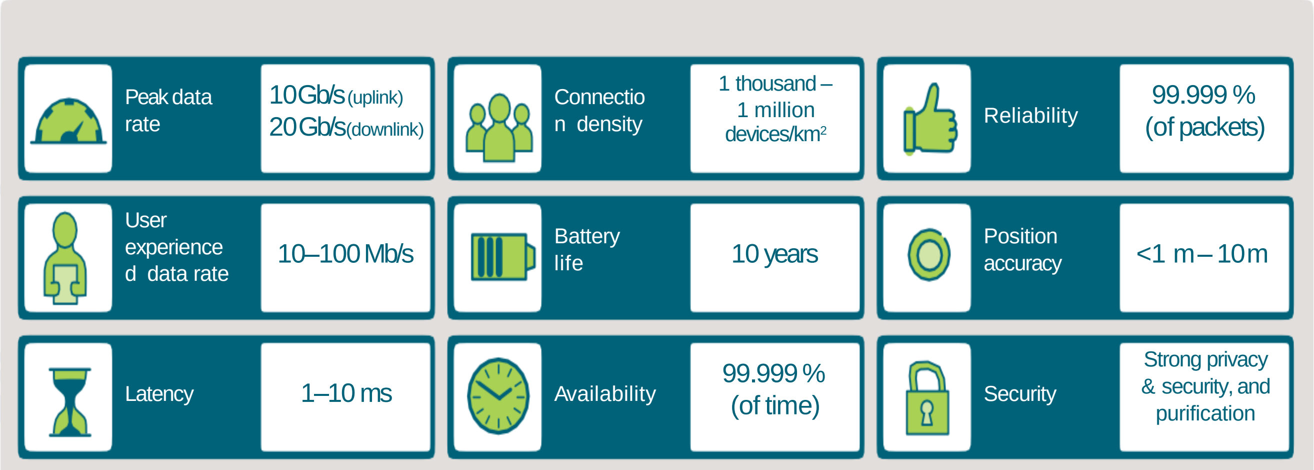
NOTE 2 – Along the presentation some references are provided concerning relevant achievements and ongoing work items of the ITU-T IMT-2020 standardization initiative

Gaps and challenges towards 5G/IMT-2020



NB: Downlink metrics shown



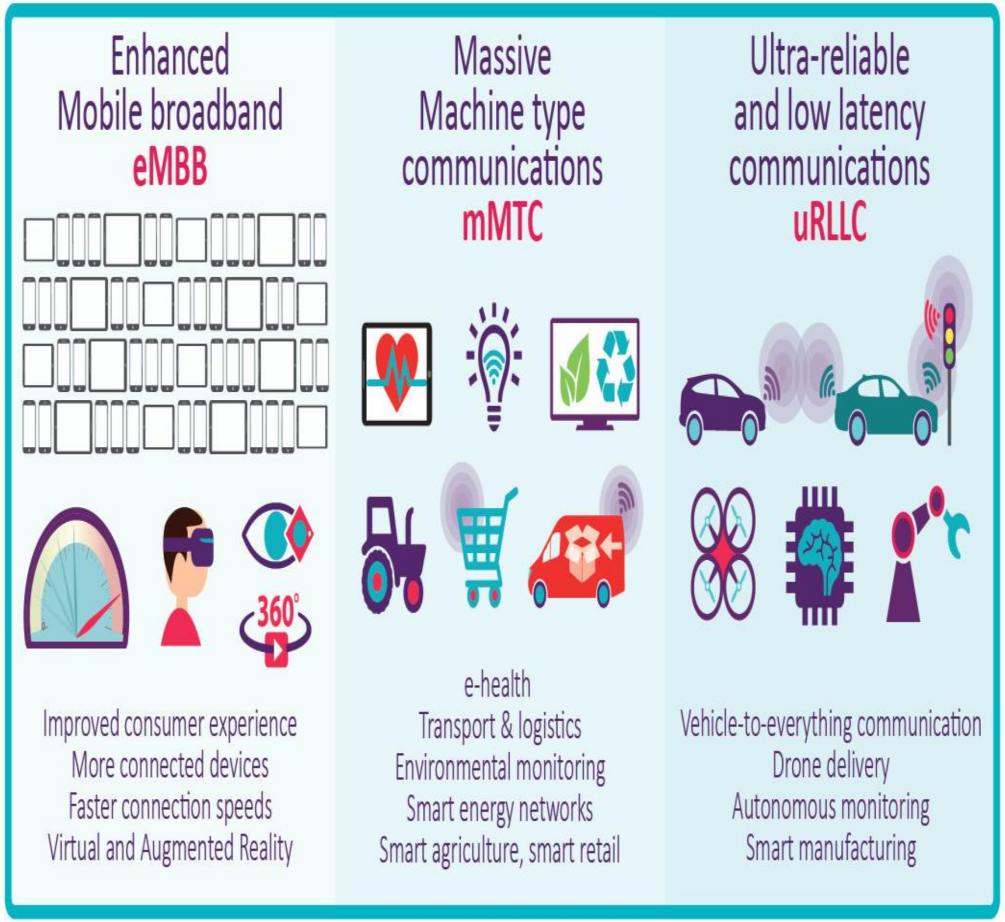


Source: ZVEI **Target key performance indicators of 5G according to ITU-R**

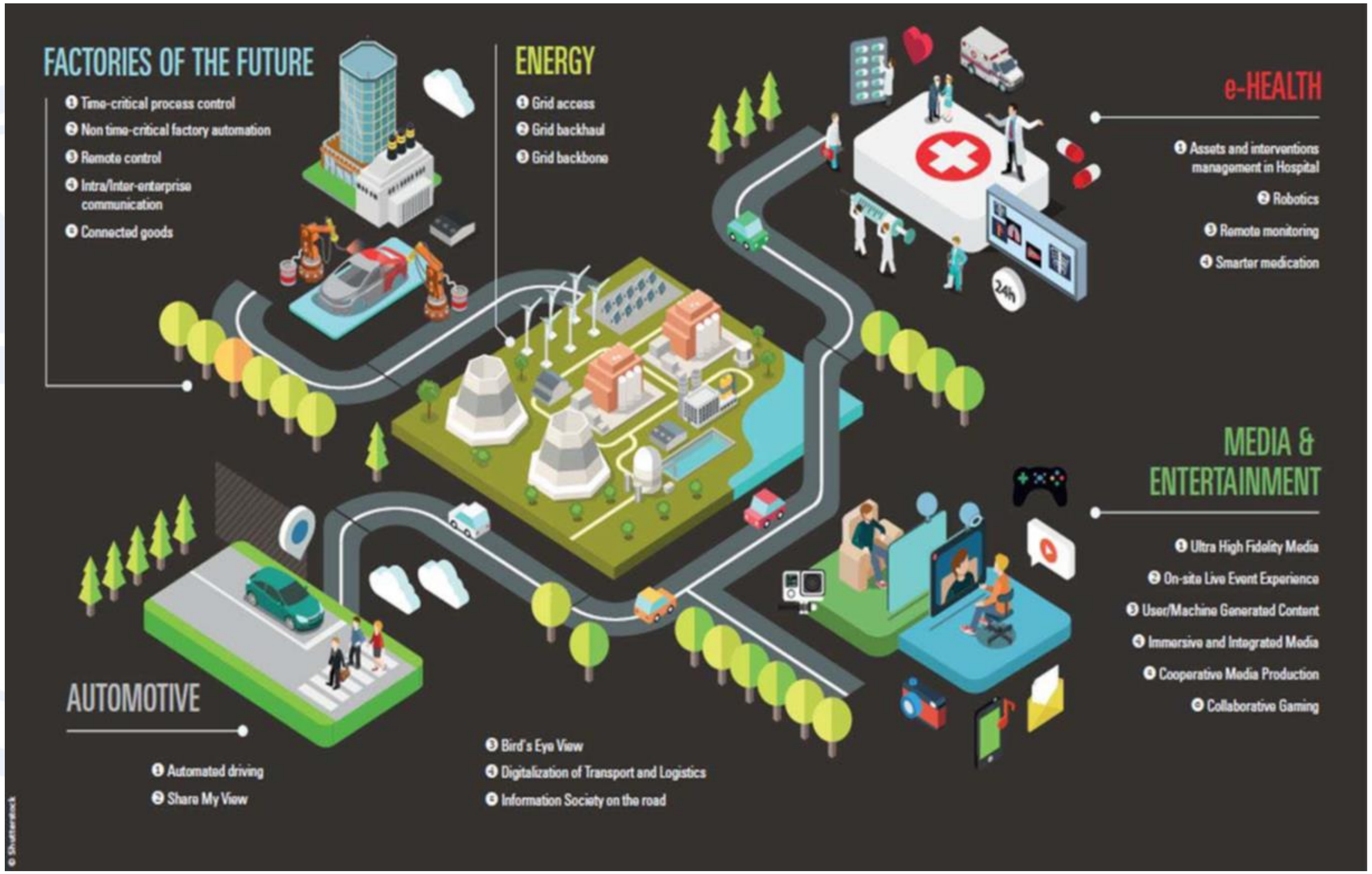
Other network dimensions with gaps for 5G/IMT-2020 expectations:

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

5G/IMT-2020 driving industrial and societal changes as enabler of a large variety of applications



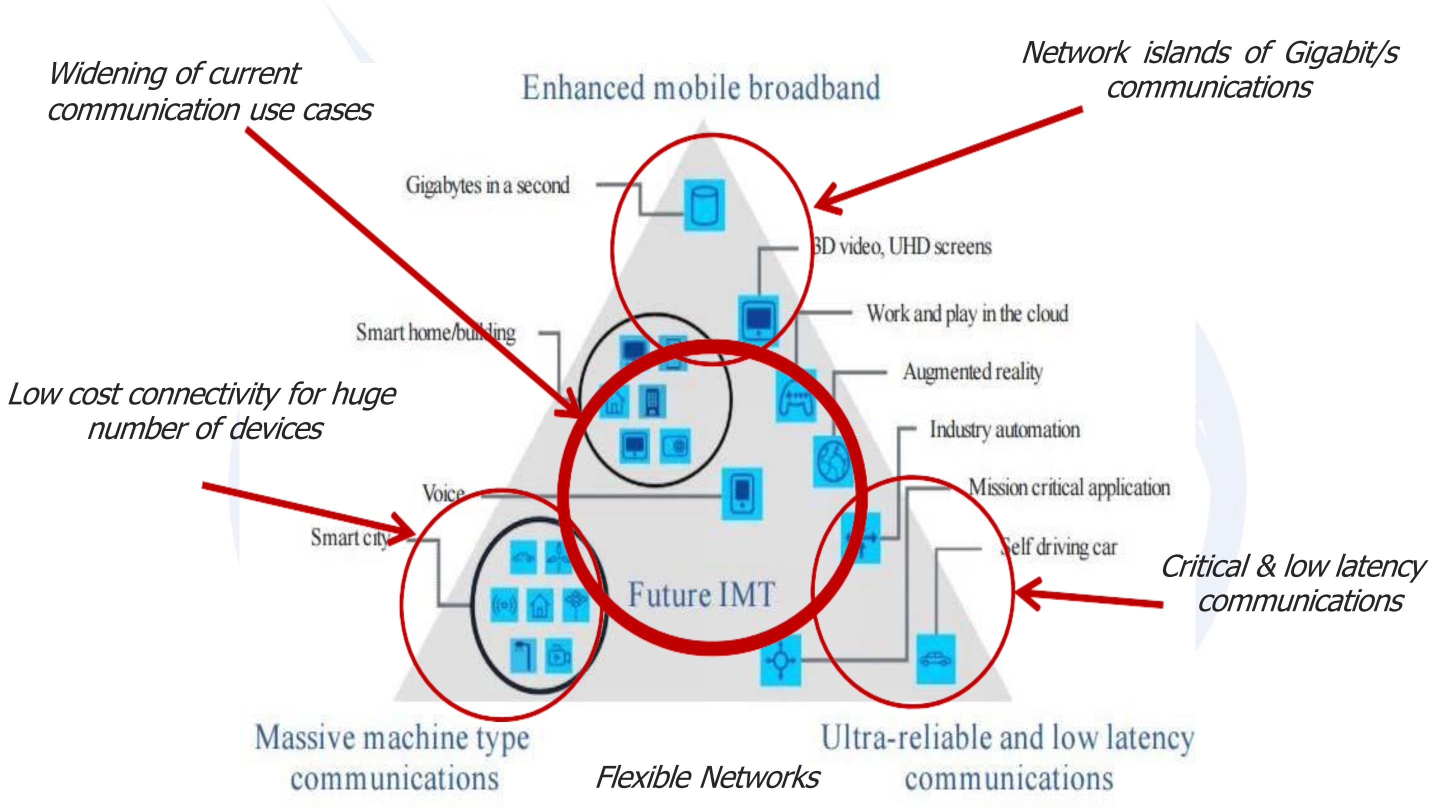
Source: Ofcom



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)*

A diversity of 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 apps and 5G/IMT-2020 infra (business models diversity in integrated ecosystem)

Support of Vertical Industries by 5G/IMT-2020 networks

A number of studies, projects and standards related initiatives are currently investigating in detail the support of verticals by 5G/IMT-2020 networks (specific requirements and functionalities, interfaces)

Foundational Siemens white paper (2016): 5G promises vs. Verticals' requirements

Category	Requirement	Explicit 5G promises (according to [1], Figure 2)	Siemens demand	Smart City	Smart Mobility	Smart Manufacturing: Process	Smart Manufacturing: Discrete	Smart Energy: Low Voltage	Smart Energy: Medium Voltage	Smart Energy: High Voltage	Smart Building
Industry-grade Service Quality	Realtime capability – Latency	5 ms (e2e)	1 ms (local) 5 ms (long distance)	-	1ms (local) 10 ms (long distance)	20ms (local) 1s (long distance)	1ms (local) 20ms (long distance)	-	25ms	5ms (long distance)	100ms
	Realtime capability –– Jitter	-	1us (local)	-	-	20ms	1us	-	25ms	1ms	-
	Bandwidth	Peak data 10 Gbps Mobile data volume 10 TB/s/km² Number of devices: 1 mio/km²	kbps ... 10Gbps	kbps (sensors) ... Mbps (video supervision) ... 10 Gbps (data centers)	10 Mbps ... 1 Gbps	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)	1 kbps per subscriber	5 Mbps per secondary substation	1Gbps along power lines	100 kbit/s (automaton stream) ... 100 Mbps (remote access, video supervision)
	Time period of information loss during failures	-	none (seamless failover)	1s	100 ms	100 ms	none (seamless failover)	minutes	25ms	none (seamless failover)	100 ms
	Availability/ coverage	-	Ubiquitous	City-level	Ubiquitous	Industrial Plant Areas	Industrial Plant Areas	Ubiquitous	Ubiquitous	Ubiquitous	City-level
	Range (distance between communication neighbors)	-	0,1 m ... 200 km	10 km	1 km (cars) ... 10 km (trains)	0,1m ... 10 km	0,1 m ... 100 m	10 km	20 km	200 km	100m
	Reliability (minimum uptime per year [%])	99,999%	100%	99,9%	100%	100%	100%	98%	99,9%	100%	99,9%
	Mobility	500km/h	500km/h	100km/h	500km/h	50km/h	50km/h	5km/h	-	-	5km/h
	Outdoor terminal location accuracy	<1m	0,1 m	1 m	0,1 m	0,1 m	0,1 m	10 m	10 m	-	0,1 m
	Multi-tenant support	yes (Network Slices)	yes								
Operation and maintenance	Non-standard operating conditions	Energy consumption reduced by factor 10	• Battery powered devices with >10years lifetime • Harsh environments (weather, vibrations, heat, dust, hazardous gases, etc.)								
	Ease of use	-	• Communication Services approach • Plug and Play Device (Sensor, Actuator, Controller) integration								
	SLA Tooling	-	Service Level Agreement (SLA) monitoring and management tools for provider and consumer								
	Service deployment time (time between service request and service realization)	90 min	hours								
	private 5G infrastructures	-	yes	-	yes	yes	yes	-	optional	yes	optional
Non-technical	Scalability: Number of devices per km²	10^6	10^5	10^5	10^4	10^5 (high density of devices)	10^5 (high density of devices)	10^4	10^3	10^3	10^5
	Globally harmonized definition of Service Qualities	-	yes	-	yes	yes (for long distance)	yes (for long distance)	-	yes	yes	-
	Technology availability	-	>20 years								
	Globally simplified certification of ICT components	-	Yes								
Assured Guarantees		-	Mandatory	Relaxed	Mandatory	Mandatory	Mandatory	Relaxed	Mandatory	Mandatory	Relaxed

Specific requirements imposed on network infrastructure ["IoT and 5G" study from AIOTI WG03 – Rel.2 published March 2019]

Use cases in different industries:

- Smart Mobility, Smart Agriculture, Smart City, Smart Energy, Smart Manufacturing, Smart Health, Tactile Internet, Tactile IoT, ITS

Goal: enabling SDOs to derive requirements for automation in vertical domains

Conclusions:

- Most 5G promises on performance capabilities satisfy the requirements of use cases
- Some requirements beyond the 5G promises: very high reliability of comms (6 9's), very low latency (<1 ms), range distance between comm neighbours, clock synchro, high positioning accuracy, non standard operating conditions, SLA tooling, suitable APIs, other technologies

Some standards related efforts addressing 5G-IoT interaction (not exhaustive)

- 3GPP, ITU-T, IEC, TMForum, GSMA, AIOTI, 5GAA, 5GACIA, 5GIA (private side of 5GPPP)

The support of diverse business models by 5G/IMT-2020 networks

The 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) benefits 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)

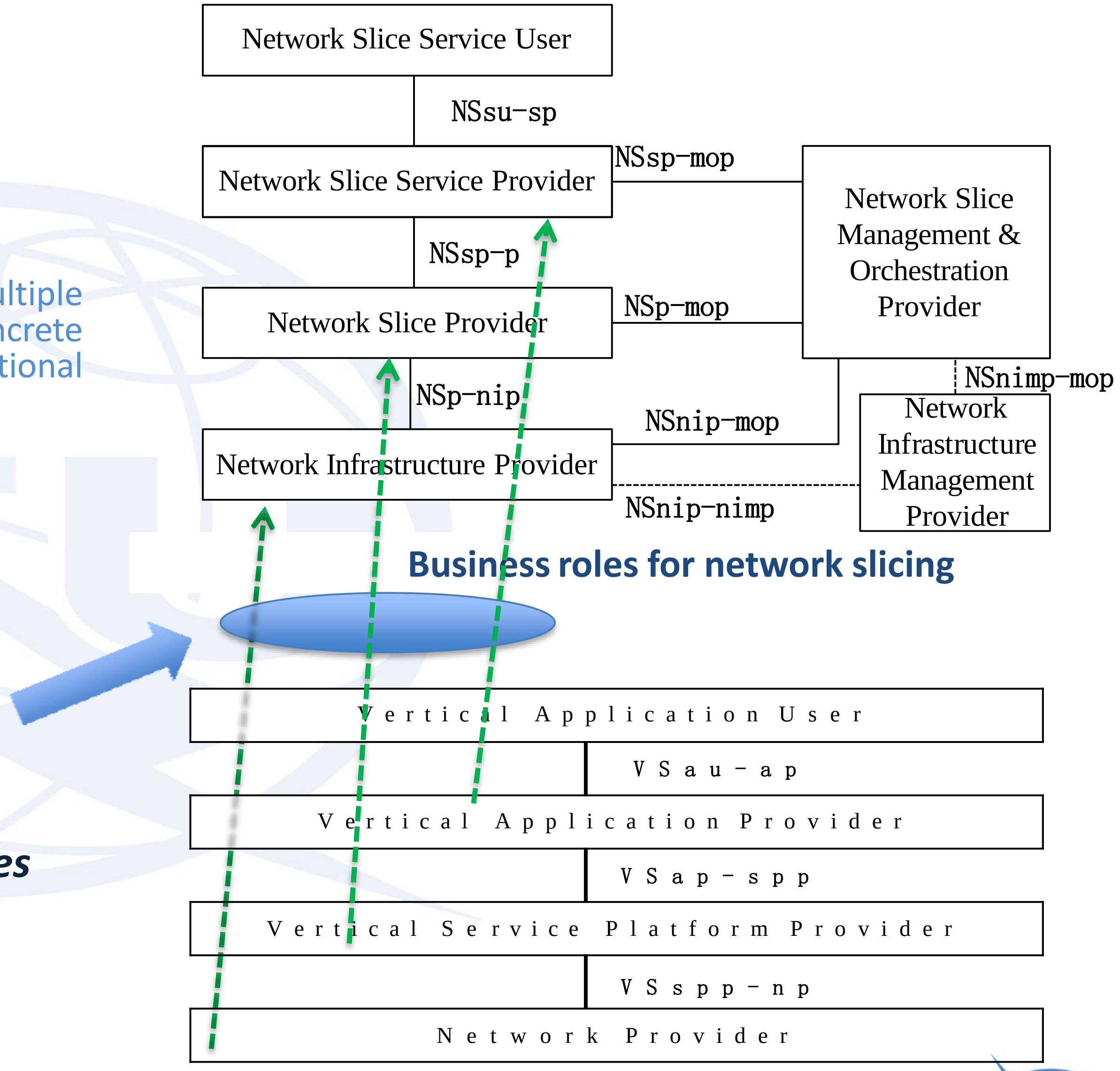
ITU-T Y.3103 “Business Role-based models in IMT2020”

- Analyses best practice use cases from different perspectives
- Identifies key business models and roles (obviously, not exhaustively)

Services investigated in Y.3103

- Network slicing based services
- Vertical services
- Device to Device services
- Augmented Reality/Virtual Reality
- Vehicle to Everything
- Edge Computing based services

Example of mapping between business roles



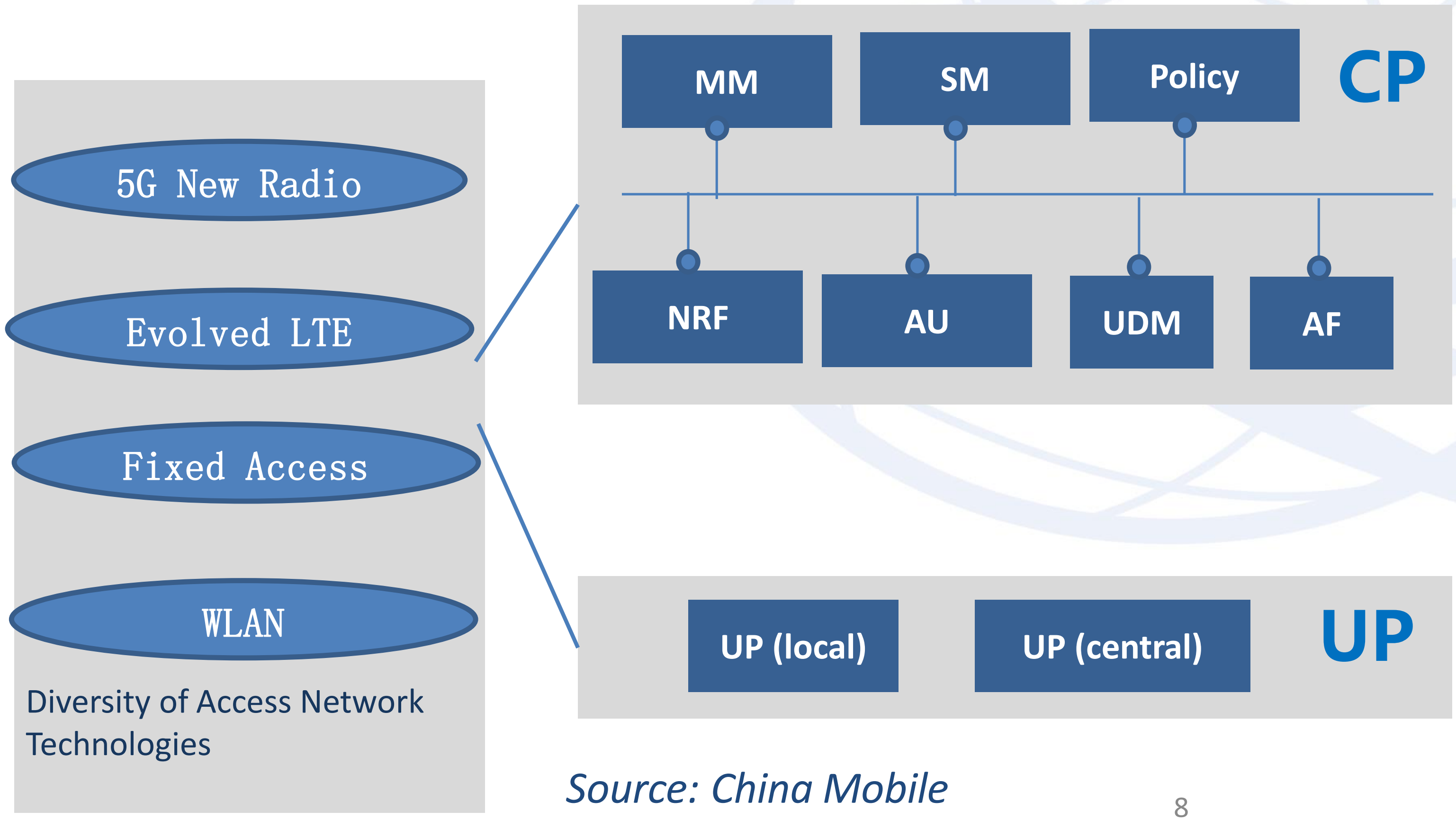
Business roles for network slicing

Business roles for Vertical services

Source: ITU-T Y.3103

5G/IMT-2020 vision - functional view

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



Source: China Mobile

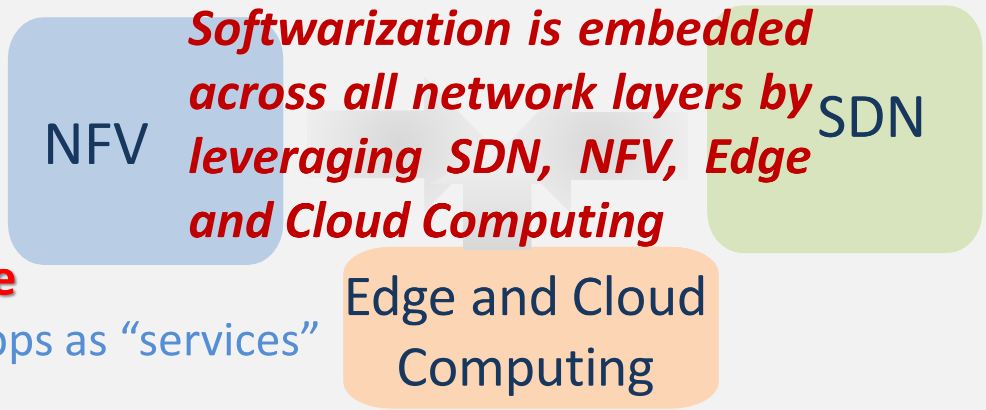
- Service-based architecture and functions interaction
- Modularization of functions
- Separation between Control Plane (CP) and User Plane (UP)
- Network Slicing
- Flexible User Plane
- Fixed Mobile Convergence (through converged Control Plane and simplified User Plane)

Network softwarization

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

Various drivers of Network softwarization

- cheap HW performance, powerful terminals and things
- Open Source SW availability
- 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' apps 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)
- **"Network services" are provisioned by using network functions instantiated at the right time and right location**

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

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

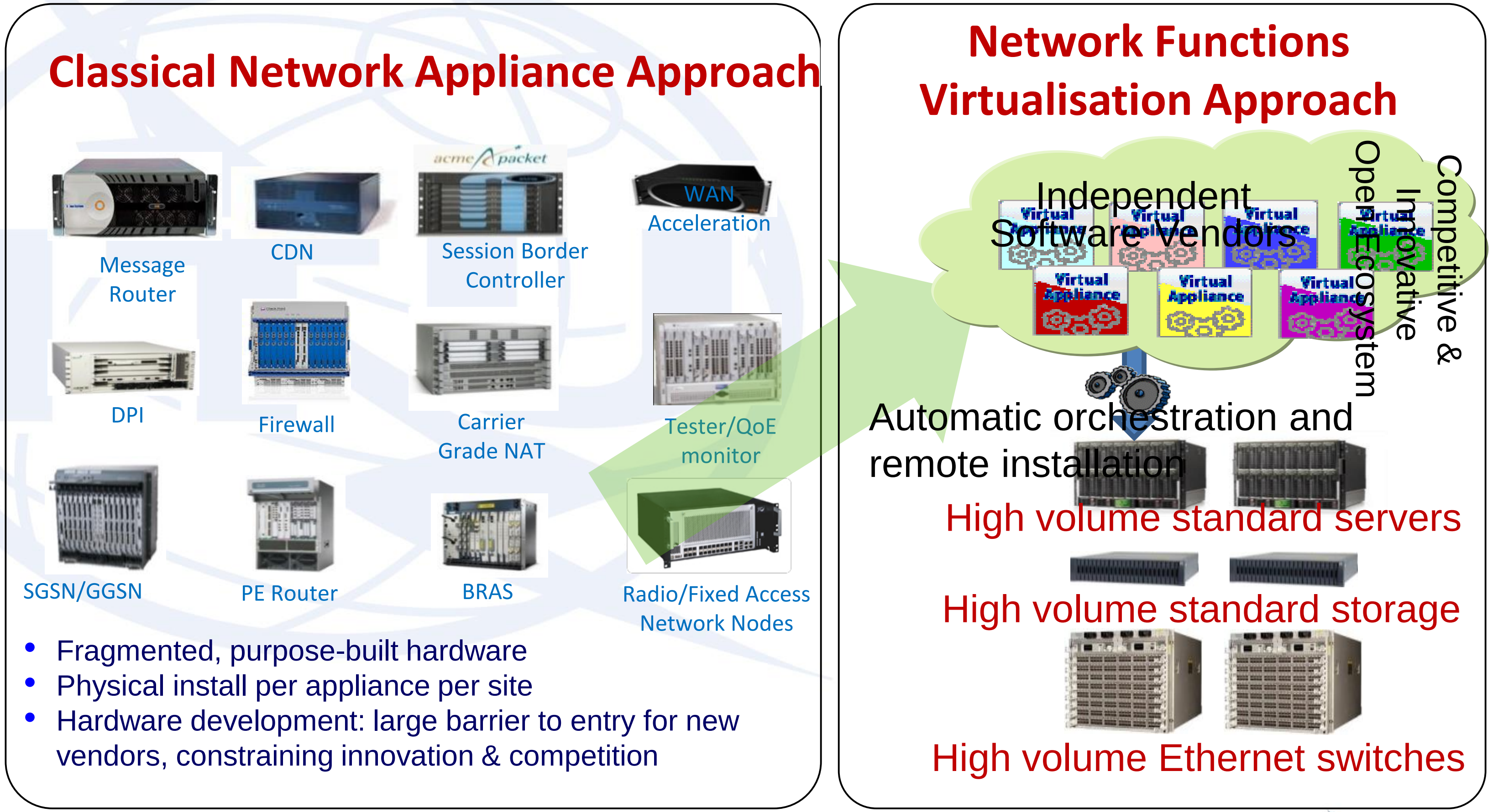
See also ITU-T Y.3150

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

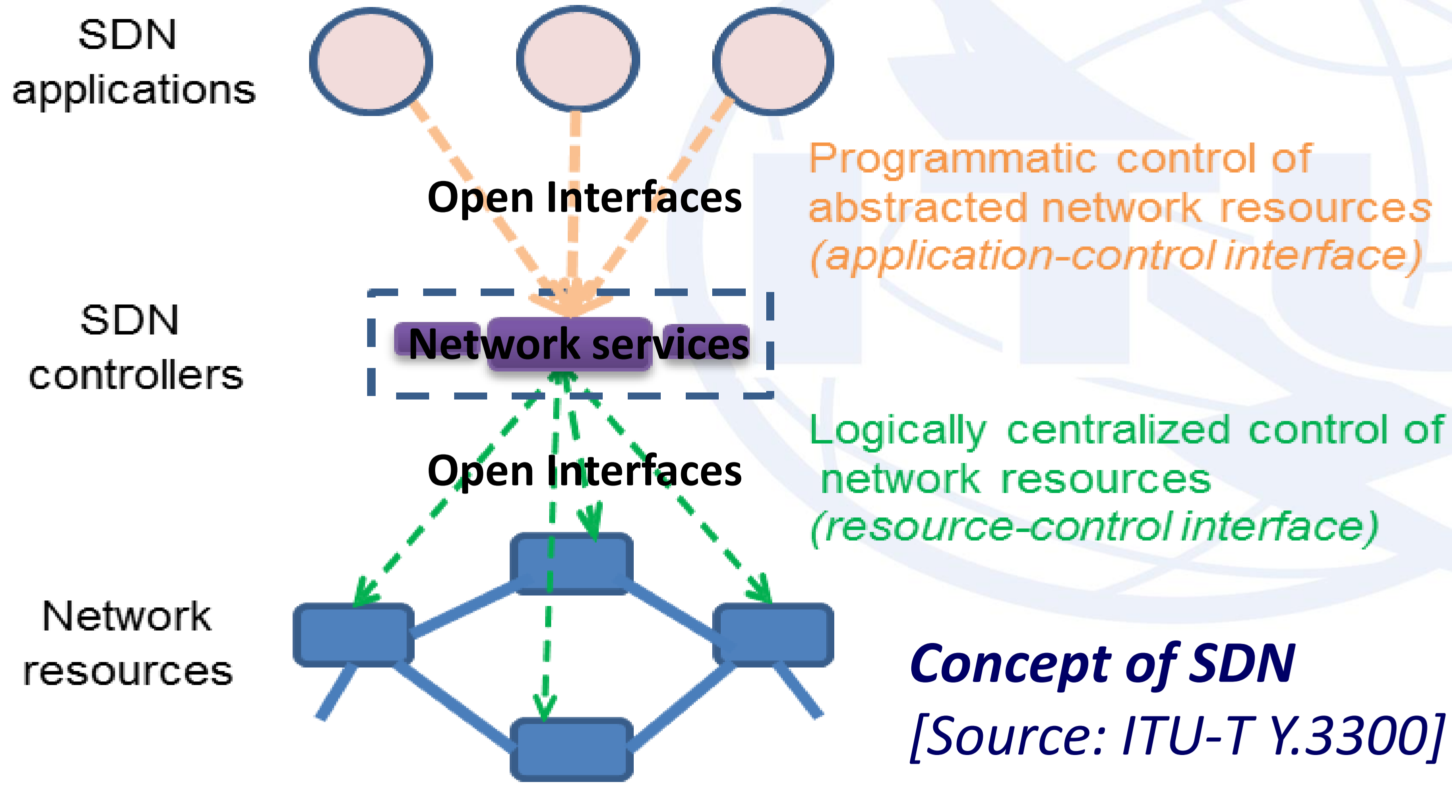


Some issues to be fully addressed, incl.

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

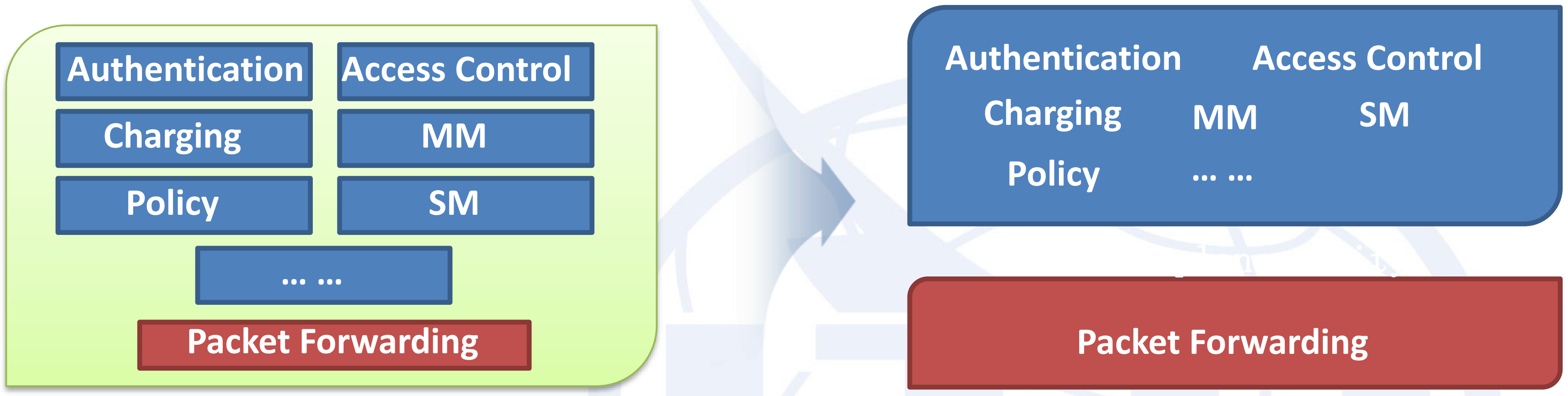


Concept of SDN
[Source: ITU-T Y.3300]

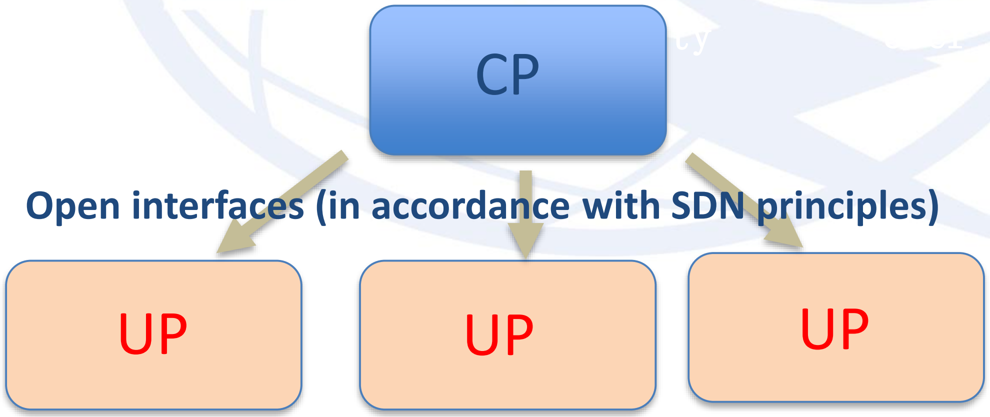
SDN benefits

- **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

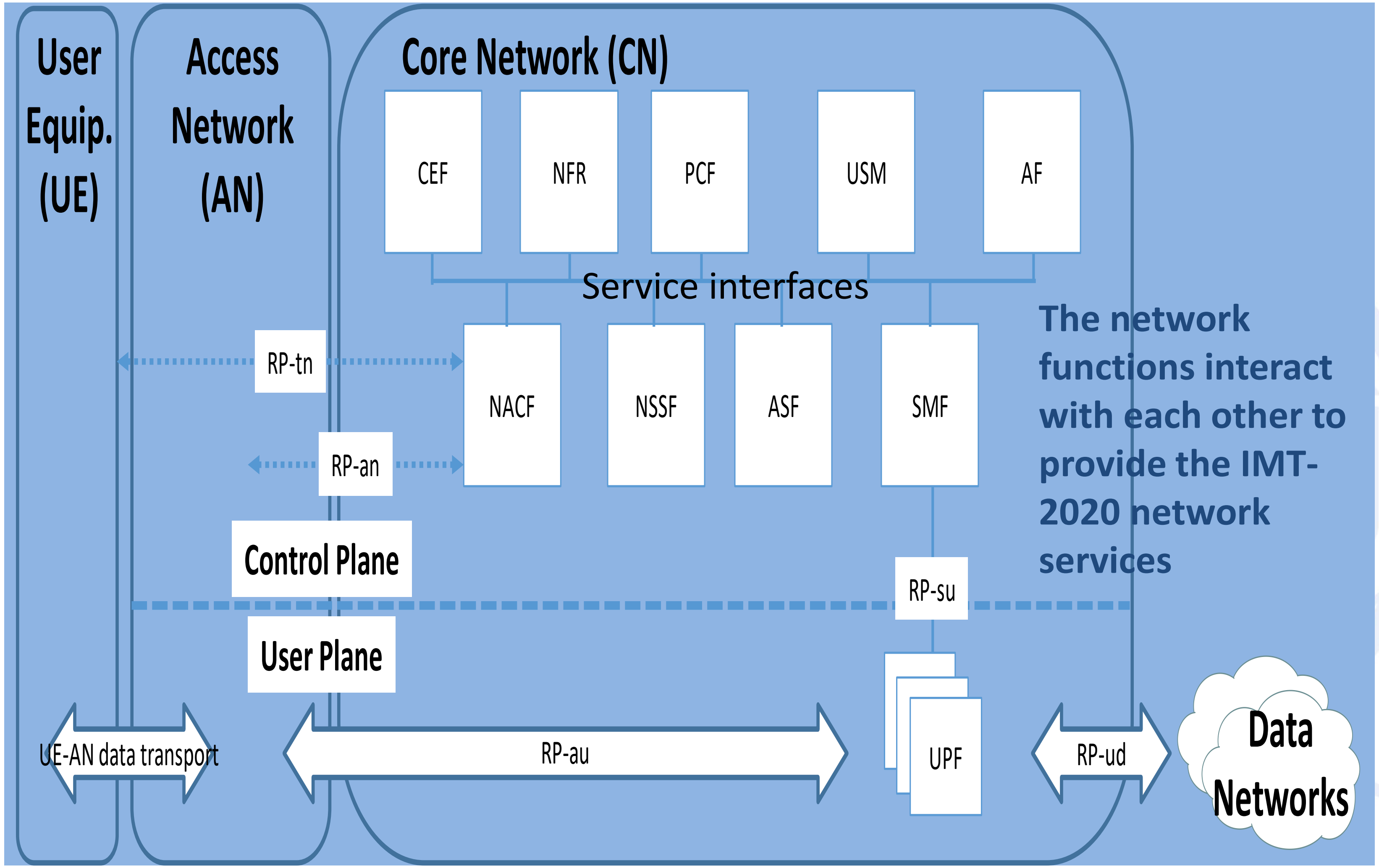


- Scalability
- Independent evolution of both planes
- Flexible network function deployment



Different User Planes (e.g. different forwarding protocols) under control of a unified Control Plane

Architecture reference model of the IMT-2020 network [ITU-T Y.3104]



Architecture reference model of IMT-2020 network and associated reference points

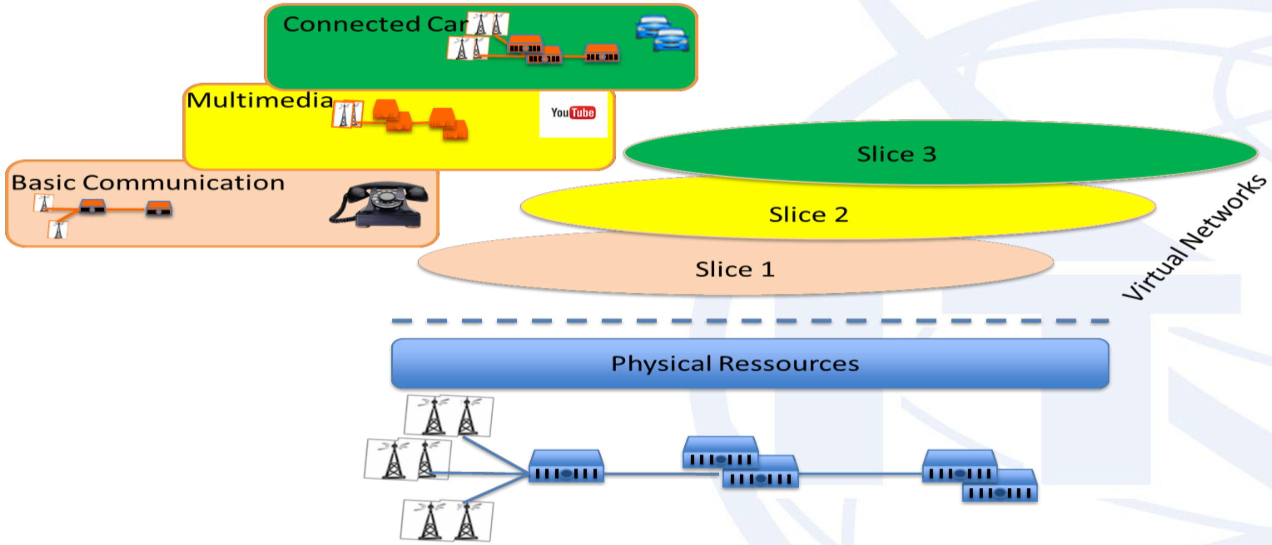
The IMT-2020 (basic) network services as identified in Y.3102 (procedures described in Y.3104)

- Registration Management (to register or deregister a UE with IMT-2020 network and establish the user context in the network)
- Connection Management (to establish and release signalling connection between UE and NACF)
- Session Management (to manage PDU sessions incl. control of PDU session tunnel establishment, modification, and release)
- Handover (unified handover management procedures according to the access agnostic common core network principle)

For the different 5G/IMT-2020 architectural aspects (not addressed by ITU-T Y.3104), the appropriate 3GPP specifications constitute - obviously - the reference standards [key specs: 3GPP TS 23.501 and TS 23.502 (Rel. 15)]

Network slicing (major feature of IMT-2020/5G): customized support of applications via dedicated logical networks over single infrastructure

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



- Each slice is architected and optimized for specific app(s)
- Each slide can have its own network architecture, engineering mechanisms and network provision
- Vertical and horizontal slicing
- Network slice instance [b-ITU-T Y.3100]: Instance of network slice, created based on network slice blueprint

Various ITU-T specifications concern network slicing, incl. Y.3112 "Framework for the support of Multiple Network Slicing"

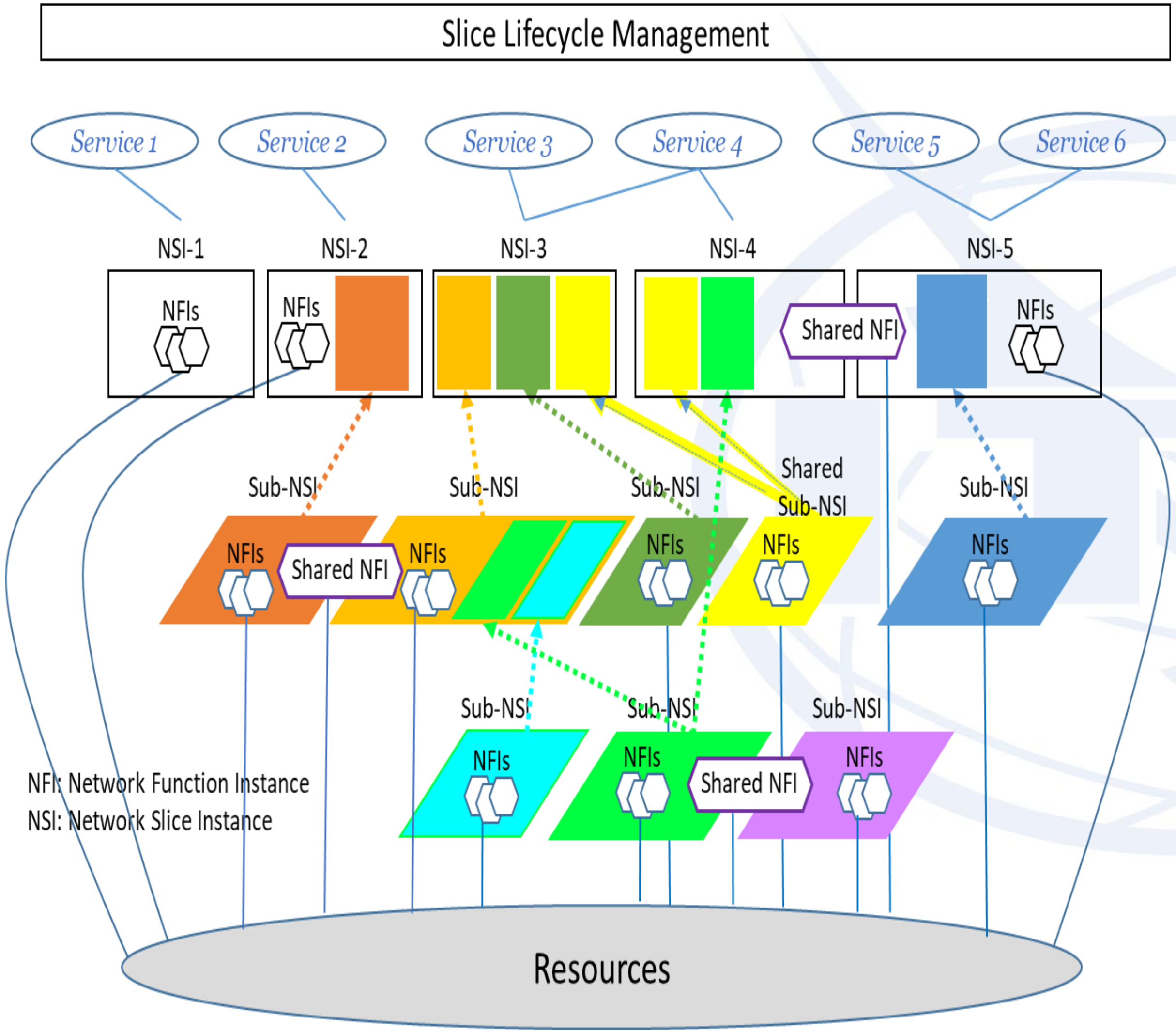
Network slice [ITU-T Y.3100]: A logical network that provides specific network capabilities and network characteristics.

Network slicing dimensions (and studies):

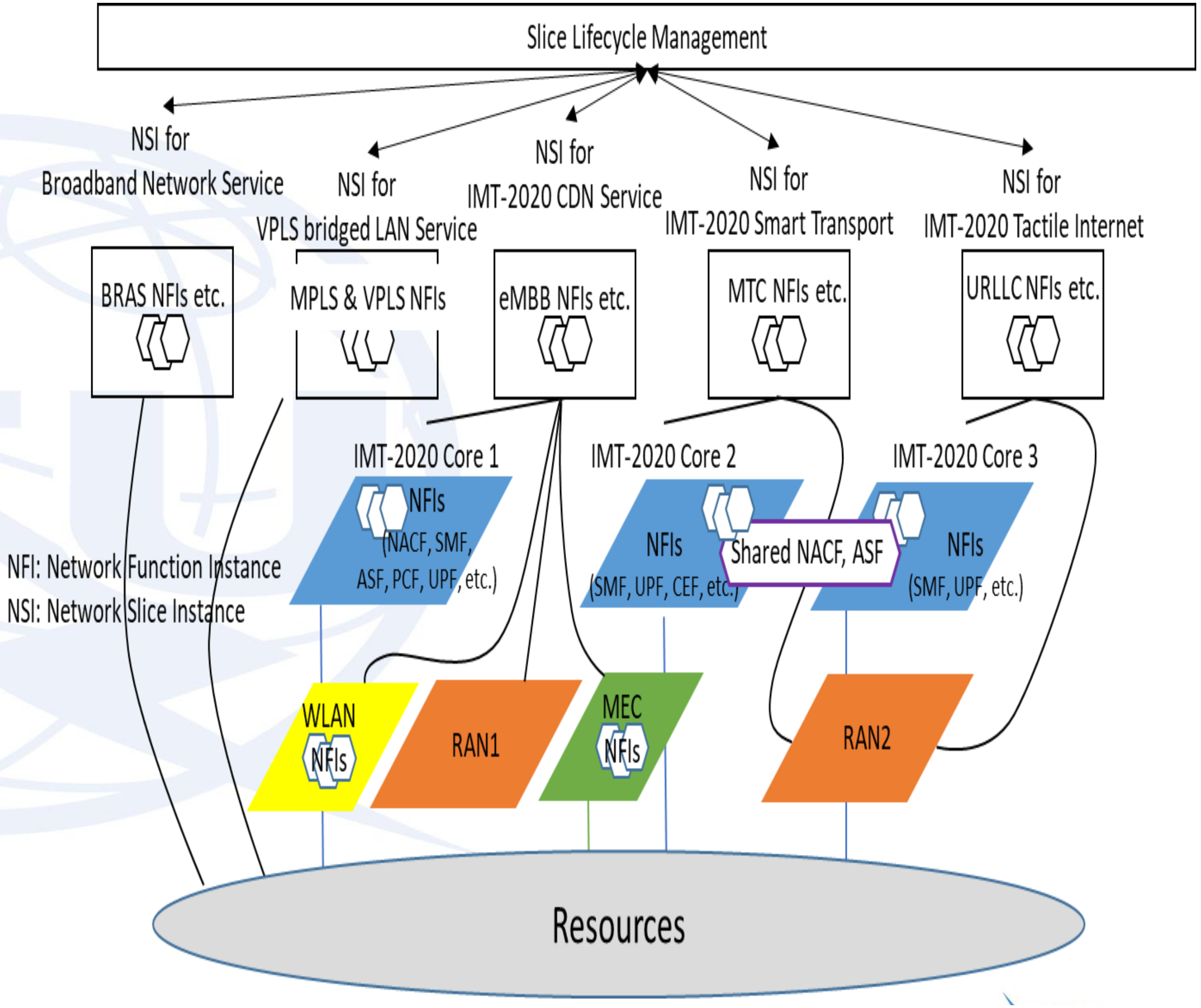
- **slice types and blueprint (template)**
- blueprint information (incl. service requirements, priority, resource isolation level, etc.)
- **static versus dynamic slice instantiation**
- service assurance and service integration
- **recursive slicing (diverse business models)**
- end-to-end versus per-domain slice (sub-network slices, incl. radio slicing), inter-domain slice federation
- per-slice network function chaining
- slice-specific network function vs shared network function
- **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

Network slice instances



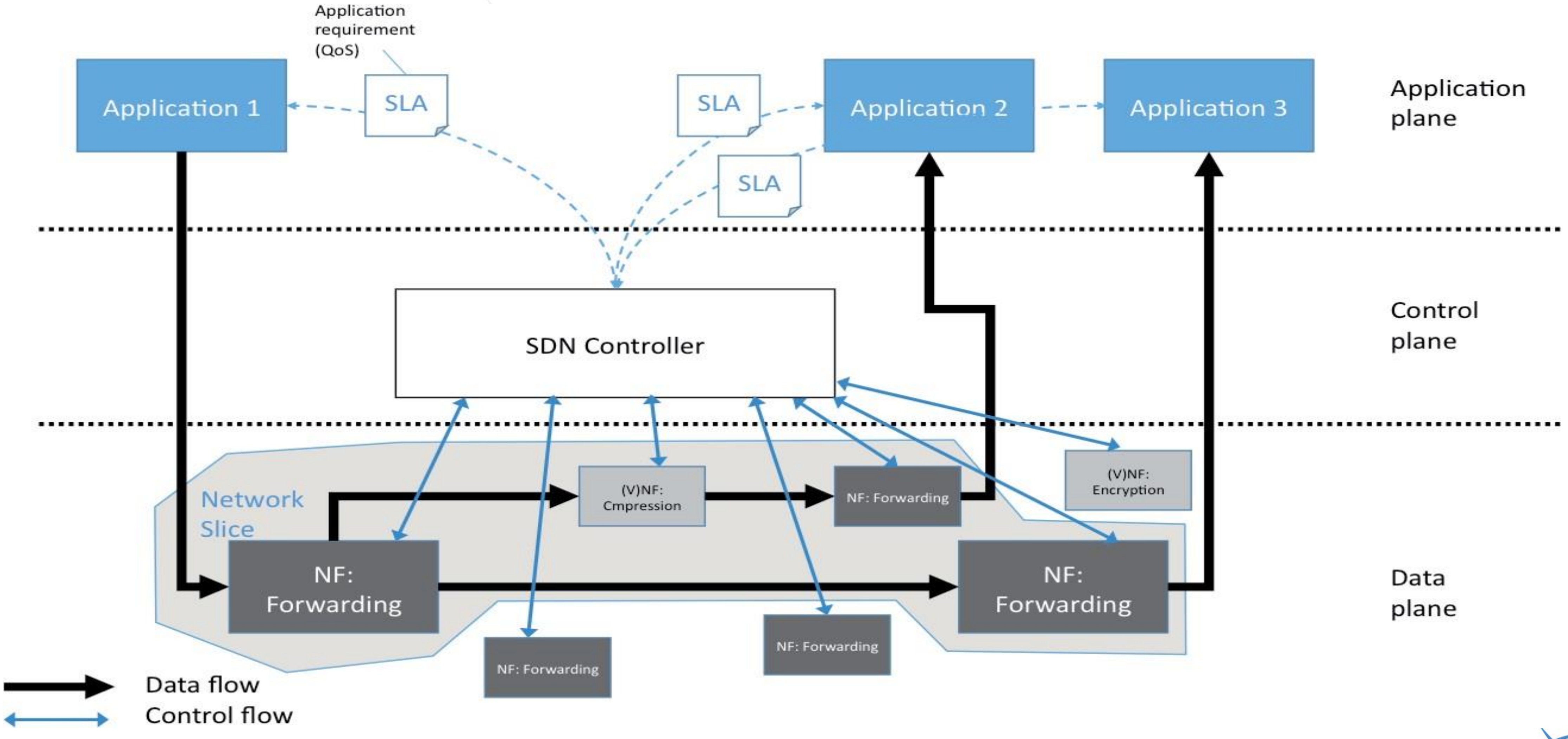
Conceptual overview of network slicing



Example of IMT-2020 network from network slicing perspective

Source: ITU-T Y.3102

Example of operations: interaction among applications, SDN, network functions and network slice



Source: Prof. Martin Wollschlaeger, TU Dresden

Network management and orchestration

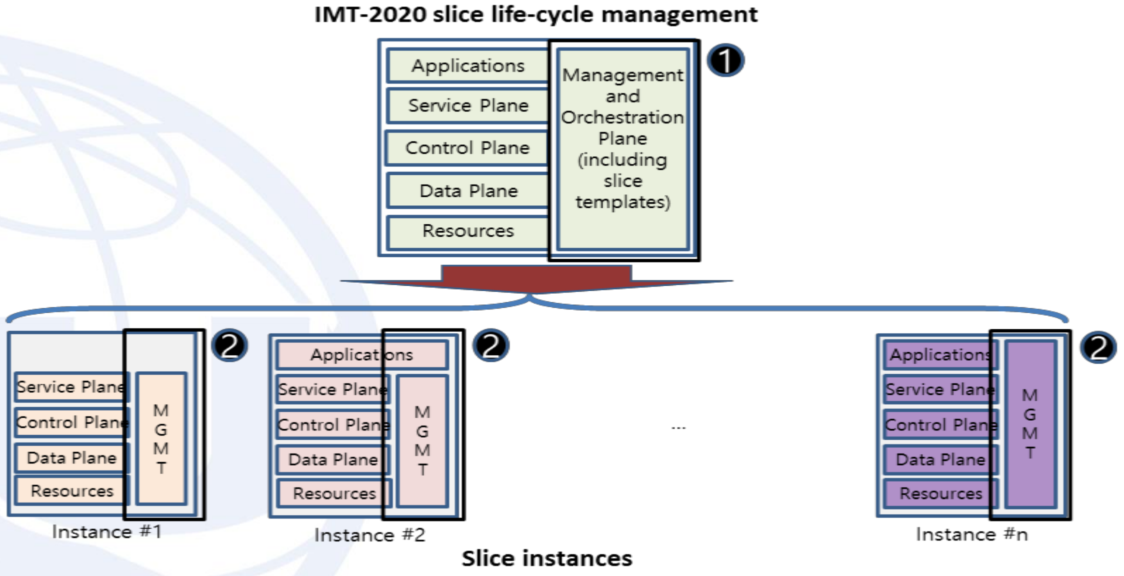
Softwarization impacts network management

- 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)

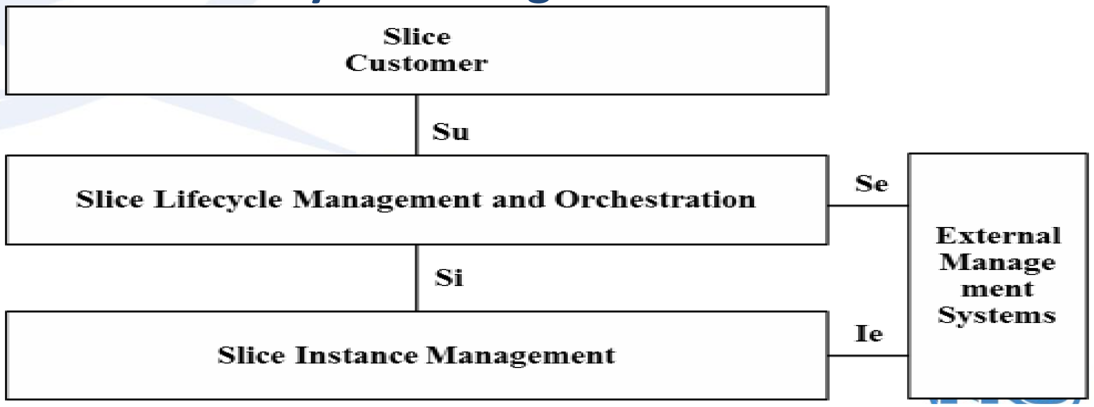
Overall network management and network slice lifecycle management

- Level of isolation between network slices
- Blueprint 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

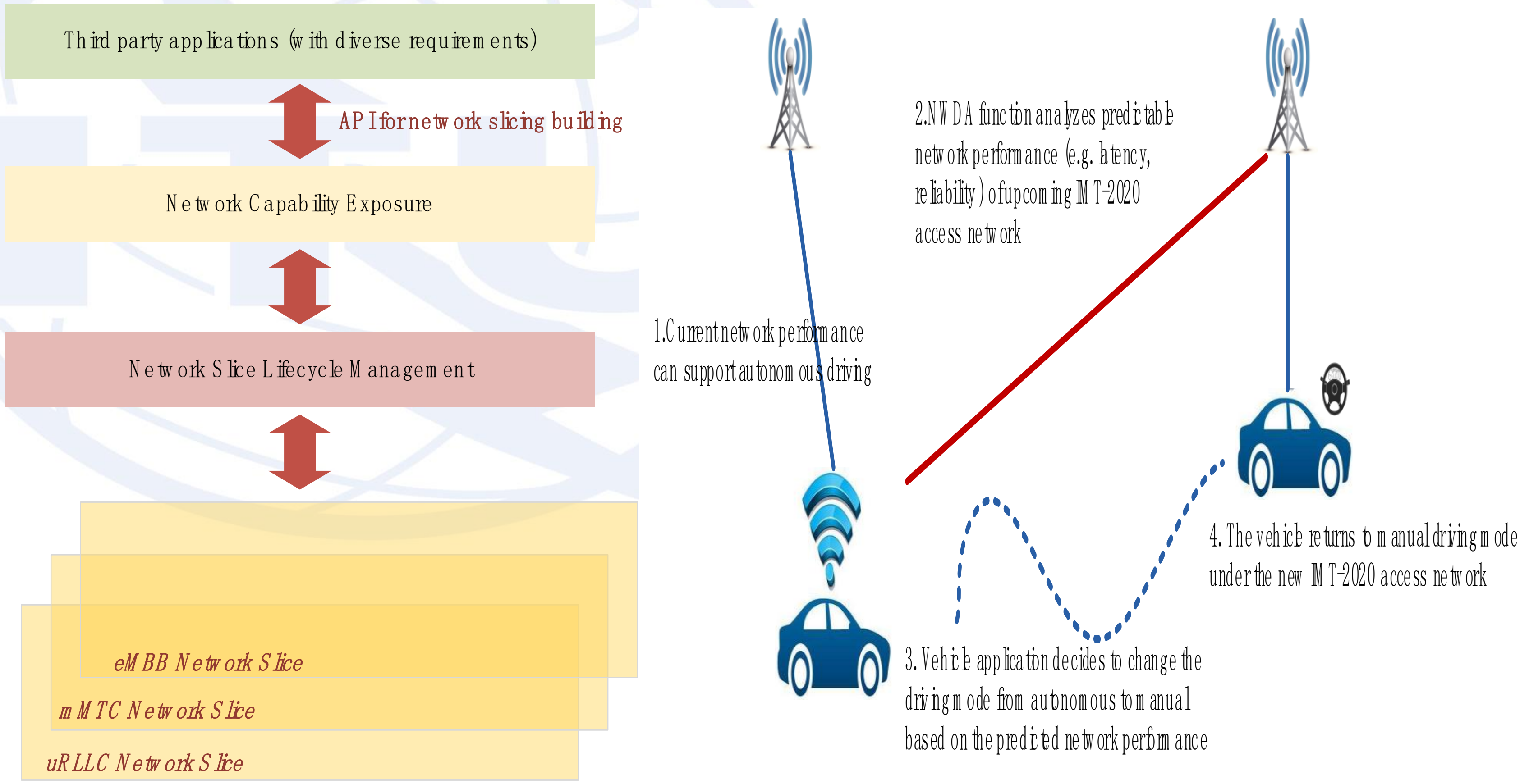
Exposure of IMT-2020 network capabilities

IMT-2020 networks are expected to bring new and enhanced capabilities.

The opening of IMT-2020 network capabilities - enabled by exposure of network information and control functions customization - **can bring new business opportunities to operators, vendors and third parties (e.g., enterprises, OTT players)**

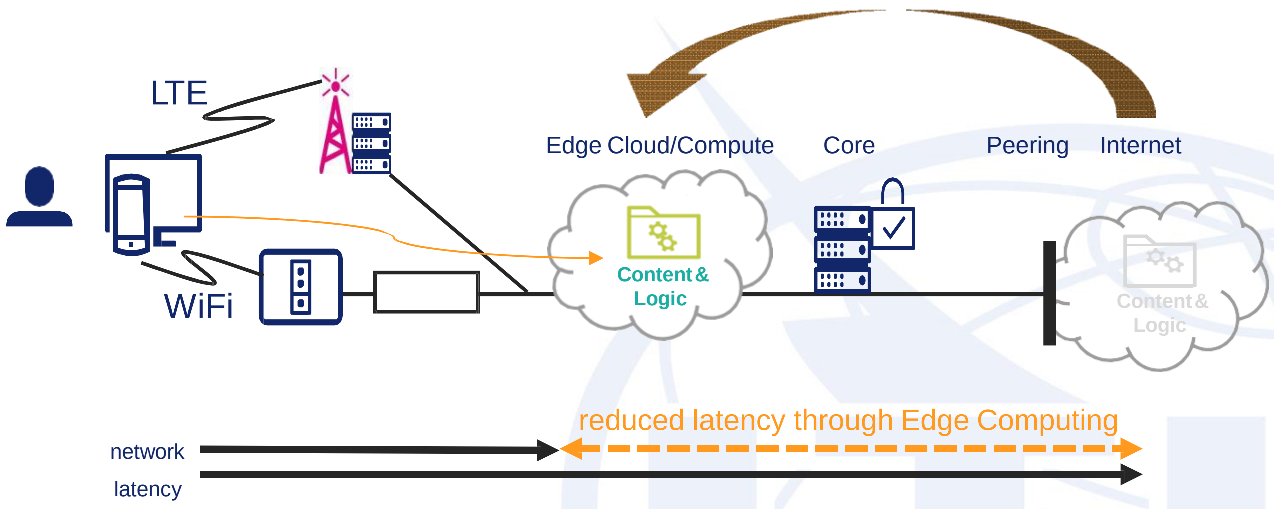
Key network capabilities expected to be exposed (but not limited to):

- Network slicing management
- Network data analytics (NWDA)
- Edge computing
- Fixed and mobile convergence
- Quality of Service



Source: ITU-T Y.3105 (Capability exposure requirements)

Edge Computing: computing and storage resources next to the user



Low latency applications

Autonomous Devices

- Drones
- Self-Driving Cars
- Robotics

Immersive Experiences

- Interactive Environments
- Virtual Reality
- Augmented Reality

Natural Interfaces

- 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 analytics) near to user
- **In-network data processing**

Edge Computing … and more: Fog/Device Computing

Some issues to be fully addressed, including

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

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 FMC unified user identity]

Source: ITU-T Y.3101

Fixed Mobile Convergence (FMC)

FMC motivations

Service perspective (seamless experience, ubiquitous service availability)

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

Network perspective (mutual coordination, evolution)

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

FMC 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 …

Introduction of Machine Learning (ML) for enhanced network intelligence

ML potential for network design, operation and optimization

- coping with increased complexity
- enhancing network operations' efficiency and robustness
- increasing network self-organization feasibility
- providing reliable predictions

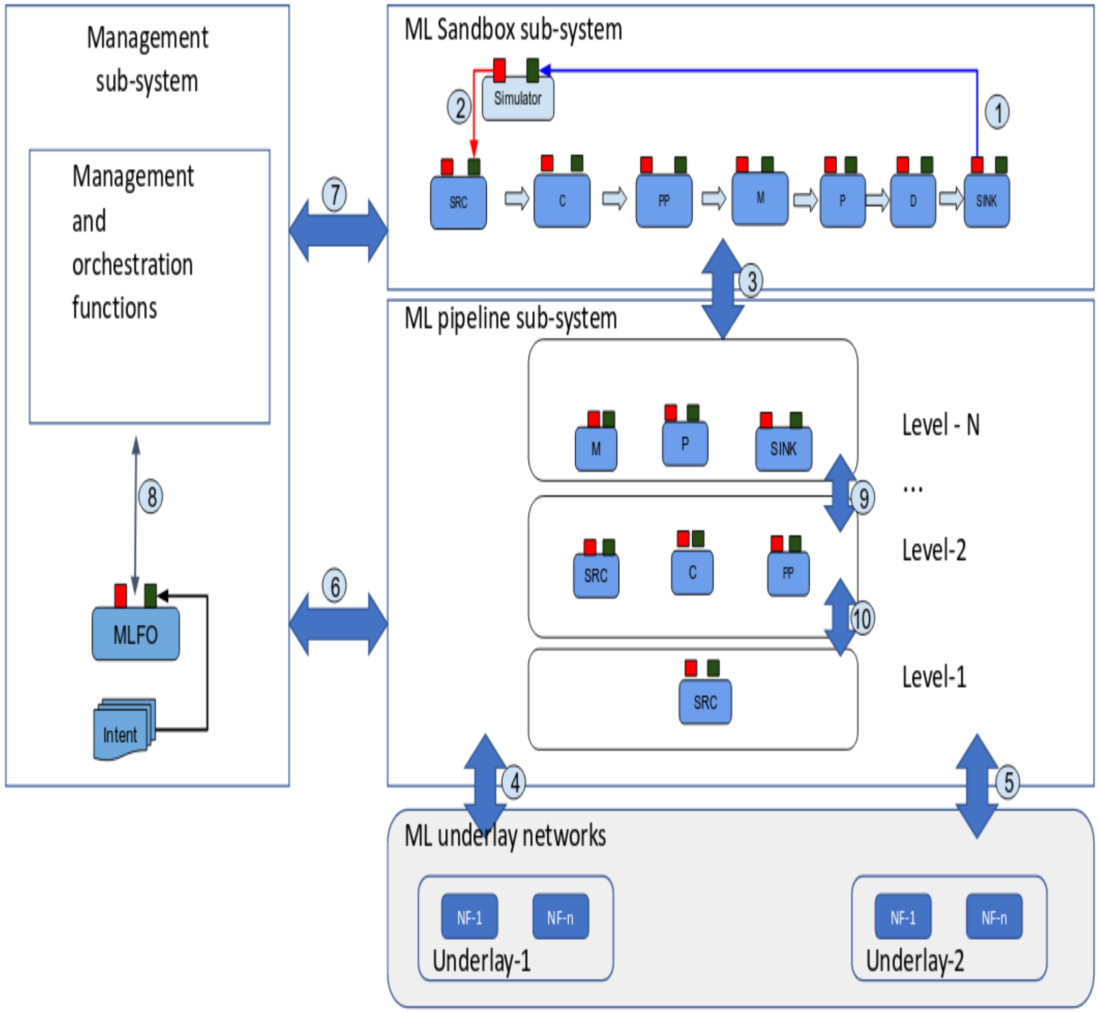
As well as ML potential to enable new advanced apps

But a number of challenges need to be addressed [beyond trust]

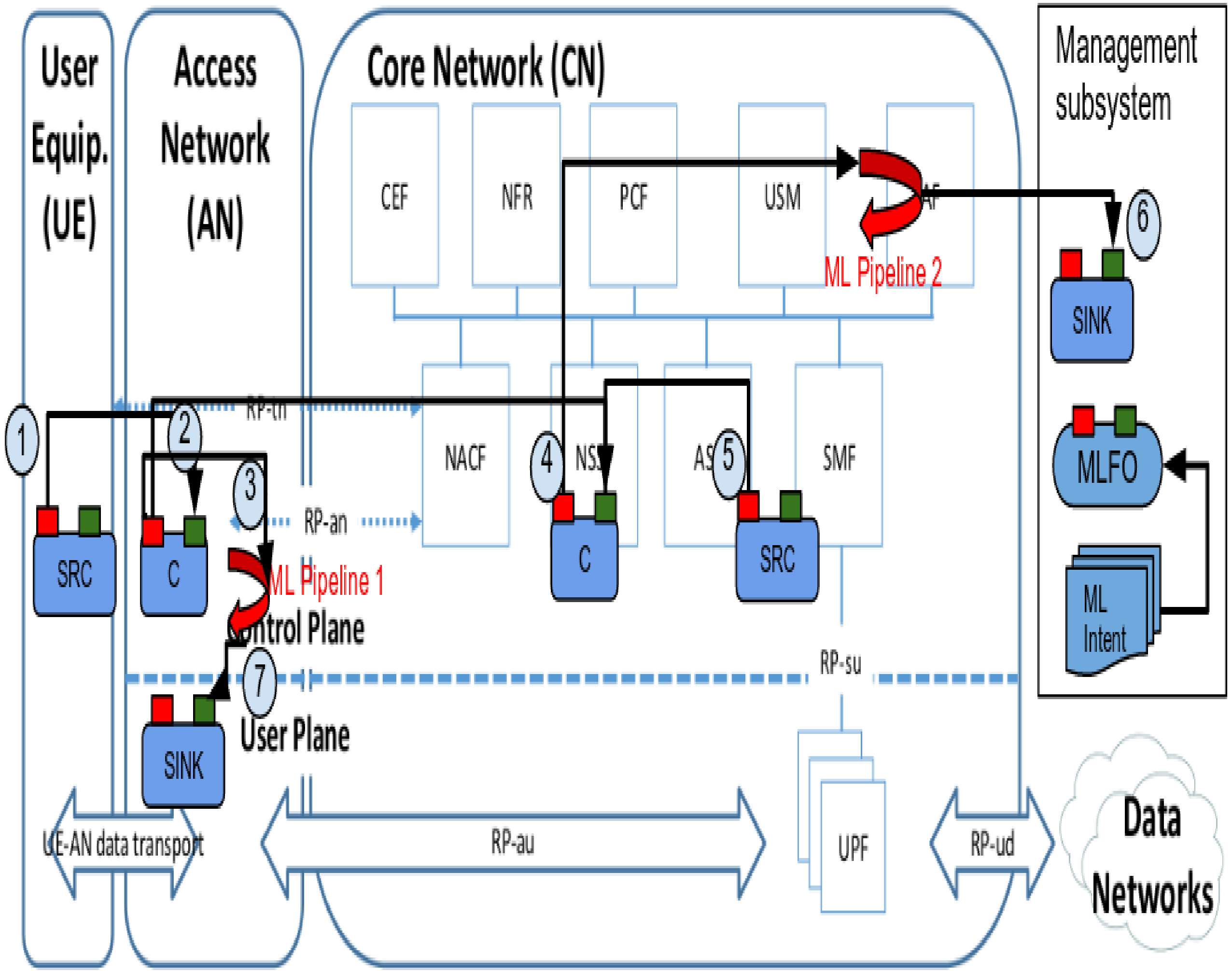
- how to deal with stringent requirements of many applications (latency)
- how to ensure robust ML given small data sets and under latency constraints
- how to deal with distribution of data at different locations and diverse data formats
- usage of distributed learning to have efficient usage of scarce resources
- how to deal with (wireless) channel noise, dynamicity and unreliability
- how to ensure good tracking capabilities
- how to exploit context info and expert knowledge (hybrid ML approaches)

Source: initial meetings of ITU-T FG-ML5G

Architectural framework for machine learning in future networks including IMT-2020 [Y.3172 – under AAP]



High level architecture



Example of realization of the high-level architecture in an IMT- 2020 network

Thank you very much for your attention

Backup information

Existing ITU-T standards related to IMT-2020 (Y.31xx series only)

Domain	Approved Recommendations
General	Y.3100: Terms and definitions for IMT-2020 network
Services, Architecture and Management	Y.3101: Requirements of the IMT-2020 network Y.3102: Framework of the IMT-2020 network Y.3103: Business Role-based Models in IMT-2020 Y.3104: Architecture of the IMT-2020 network Y.3105: Requirements of capability exposure in the IMT-2020 network Y.3106 (draft): QoS functional requirements for the IMT-2020 network Y.3110: IMT-2020 Network Management and Orchestration Requirements Y.3111: IMT-2020 Network Management and Orchestration Framework Y.3112: Framework for the support of Multiple Network Slicing Y.3130: Requirements of IMT-2020 fixed- mobile convergence Y.3150: High level technical characteristic of network softwarization for IMT-2020 Y.3151 (draft): High-level technical characteristics of network softwarization for IMT-2020 - part: SDN Y.3152 (draft): Advanced Data Plane Programmability for IMT-2020 Y.3170: Requirements for machine learning-based quality of service assurance for the IMT-2020 network Y.3172 (draft): Architectural framework for machine learning in future networks including IMT-2020 Y.3100-series Supplement 44: Standardization and open source activities related to network softwarization of IMT-2020