Wireless Technology Applications
5G Radio Access Technology

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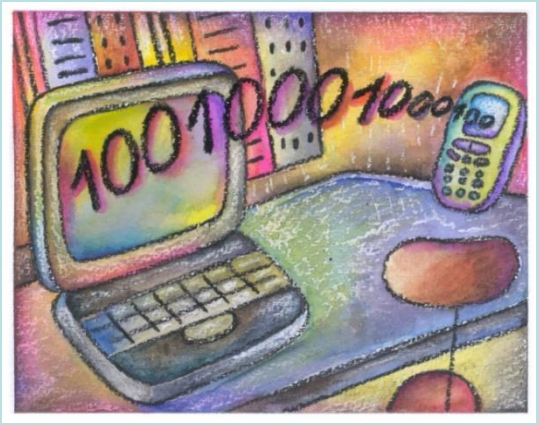

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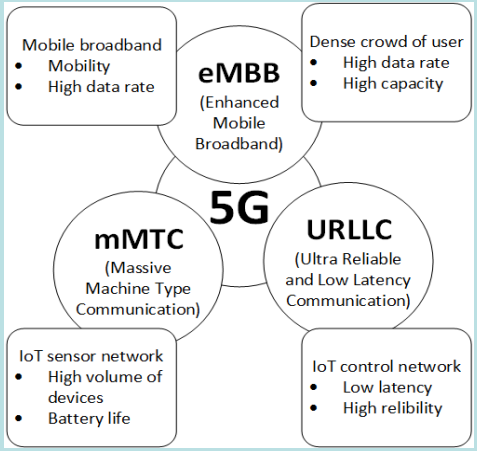
What is 5G wireless technology?

5G wireless access technology addresses three key areas and put into four different usage scenarios:

- enhanced mobile broadband (eMBB),
- massive machine type communication (mMTC) and
- ultra-reliable and low latency communication (URLLC)



5G Physical layer features

- 5G new radio (NR) offers a flexible interface

Parameter	FR1, 450 MHz – 6000 MHz	FR2, 24.250 GHz – 52.600 GHz
Carrier aggregation	Up to 16 carriers	
Bandwidth per carrier	5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 90, 100MHz	50, 100, 200, 400 MHz
Subcarrier spacing	15, 30, 60 kHz	60, 120, 240 (not for data) kHz
Max. number of subcarriers	3300 (FFT4096 mandatory)	
Modulation scheme	QPSK, 16-QAM, 64-QAM, 256-QAM; uplink also supports π/2-BPSK (only DFT-s-OFDM)	
Radio frame length	10ms	
Subframe duration	1 ms (alignment at symbol boundaries every 1 ms)	
Massive MIMO scheme	Max. 2 codewords mapped to max 8 layers in downlink and to max 4 layers in uplink	
Duplex mode	TDD/FDD	TDD
Access scheme	DL: CP-OFDM; UL: CP-OFDM, DFT-s-OFDM	

5G Physical layer features

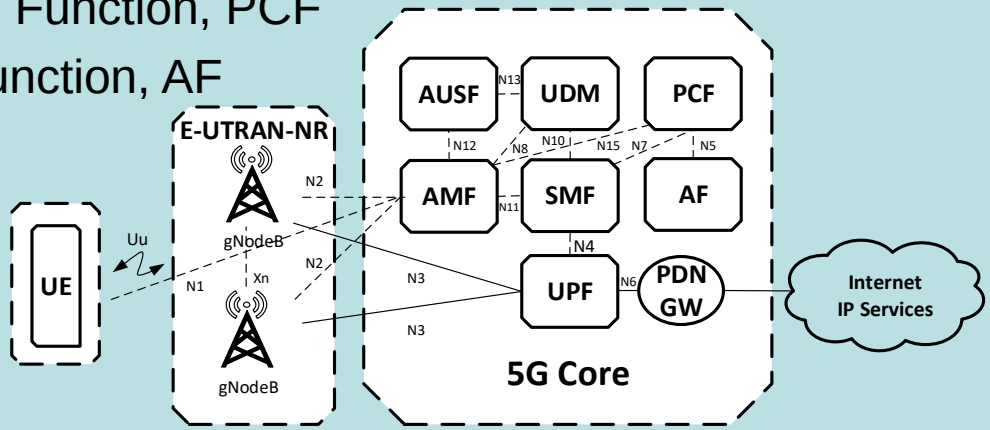
- 5G Physical layer features

Features	Benefits
mMIMO: massive MIMO	Extends the concept of MIMO to a larger number of transmitters and receivers (> 16 antenna elements) For low band, achieves higher data rates For high bands, allows higher transmission distances.
Adaptive Modulation and variable error correction encoding per RF burst	Ensures a robust RF link while maximizing the number of bits/ symbol for each subscriber unit. Supports BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM.
TDD and FDD duplexing support	Address varying worldwide regulations where one or both may be allowed
Flexible channel widths (e.g. 5MHz, 10MHz, 15MHz, etc)	Provides the flexibility necessary to operate in many different frequency bands with varying channel requirements around the world.
Designed to support smart antenna systems	Smart antennas are fast becoming more affordable and as these costs come down their ability to suppress interference and increase system gain will become important to BWA deployments.

Network Architecture of 5G

5G Network Architecture consists of :

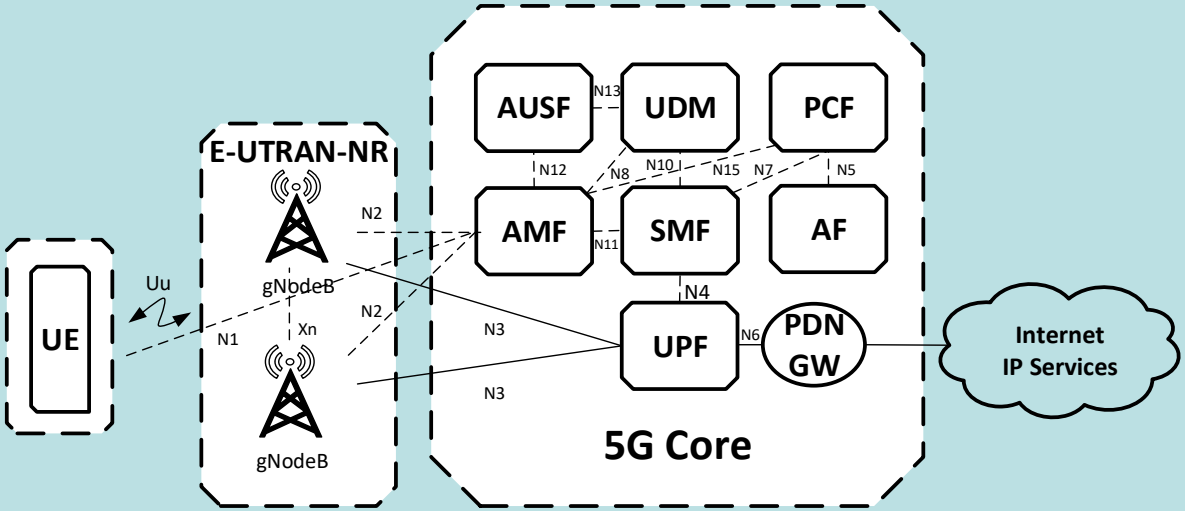
- gNodeB
- Access and Mobility Function, AMF
- User Plane Function (UPF)
- Session Management Function, SMF
- Authentication Server Function, AUSF
- Unified Data Management, UDM
- Policy Control Function, PCF
- Application Function, AF



Network Architecture of 5G

gNodeB

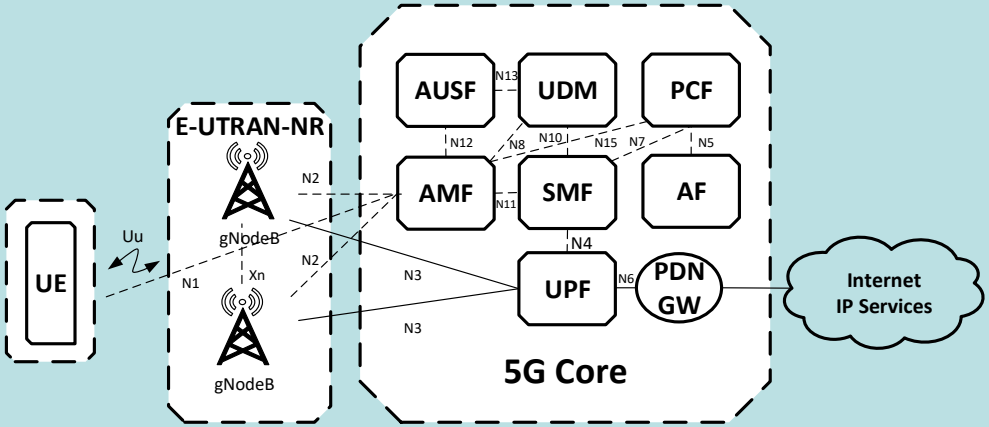
- Next Generation RAN or NG-RAN, architecture is the distributed concept
- The gNodeB (5G base-station) is split into gNodeB-Central Unit (CU) and
- gNodeB- Distributed Unit (DU) where the CU can be placed in the cloud infrastructure.



Network Architecture of 5G

Access and Mobility Function, AMF

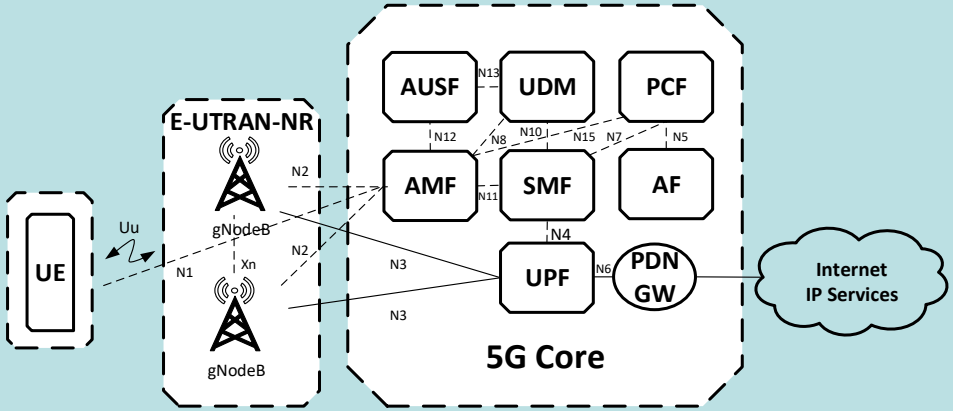
- AMF performs most of the functions that the MME performs in a 4G network
- Termination of RAN Control Plane interface, Termination of NAS (Non Access Stratum), NAS ciphering and integrity protection
- Mobility Management
- Lawful intercept (for AMF events and interface to Lawful Intercept System)
- Transparent proxy for routing access authentication and SM (Signalling Message) messages
- Access Authentication, Authorization, Security Anchor Function (SEA)



Network Architecture of 5G

User Plane Function (UPF)

- QoS handling for User plane
- Packet routing & forwarding
- Packet inspection and Policy rule enforcement
- Lawful intercept (User Plane)
- Traffic accounting and reporting
- Anchor point for Intra-/Inter-RAT mobility (when applicable)
- Support for interaction with external DN (Data Network) for transport of signalling for PDU session authorization/authentication by external DN

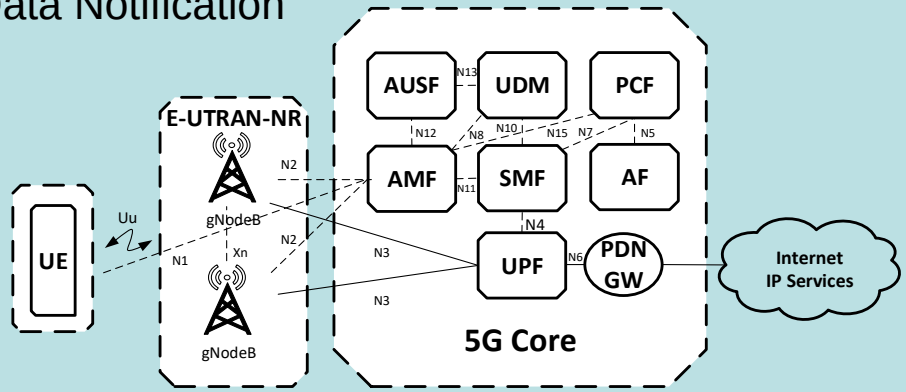


Network Architecture of 5G

Session Management Function, SMF

a fundamental element of the 5G Service-Based Architecture (SBA)

- UE IP address allocation & management (including optional Authorization)
- Selection and control of User Plane function
- Termination of interfaces towards Policy control and Charging functions
- Control part of policy enforcement and QoS
- Lawful intercept (for Session Management events and interface to Lawful Intercept System)
- Termination of Session Management parts of NAS messages
- Downlink Data Notification



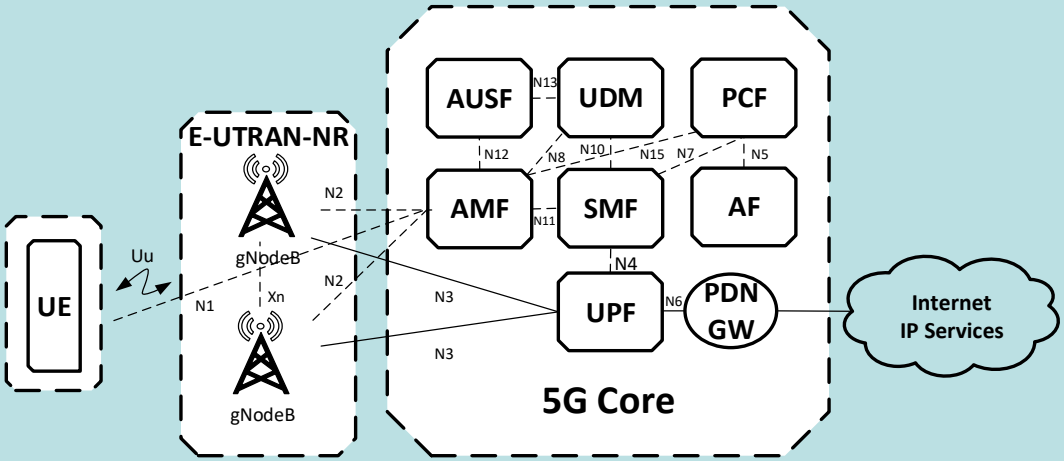
Network Architecture of 5G

Authentication Server Function, AUSF

- Performs authentication processes with the UE

Unified Data Management, UDM

- Authentication Credential Repository and Processing Function (ARPF);
- this function stores the long-term security credentials used in authentication for AKA (Authentication and Key Agreement)
- Storing of Subscription information



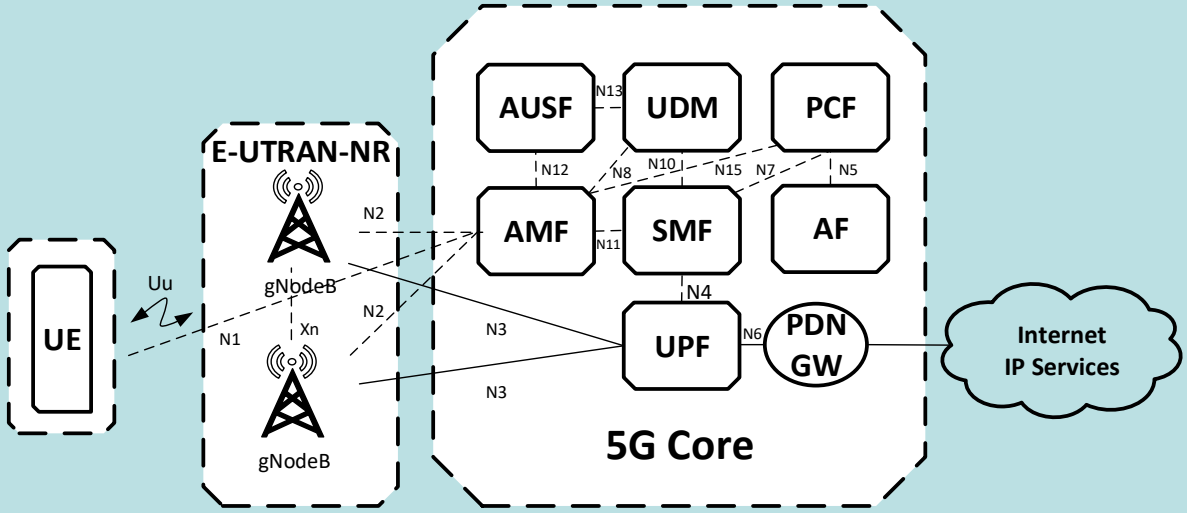
Network Architecture of 5G

Policy Control Function, PCF

- Support of unified policy framework to govern network behaviour
- Policy rules to control plane function(s) that enforce them

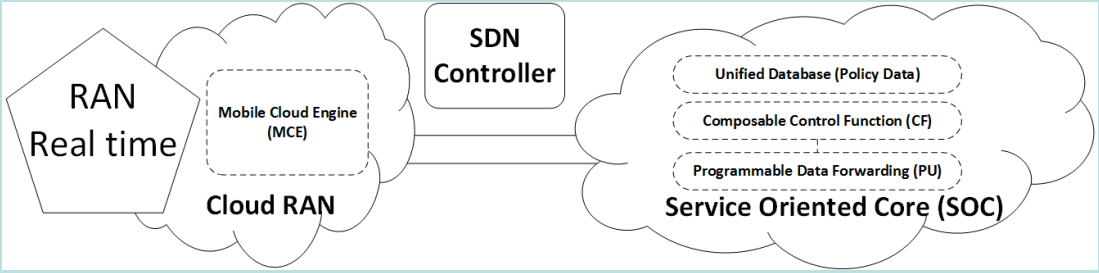
Application Function, AF

- AF requests dynamic policies and/or charging control



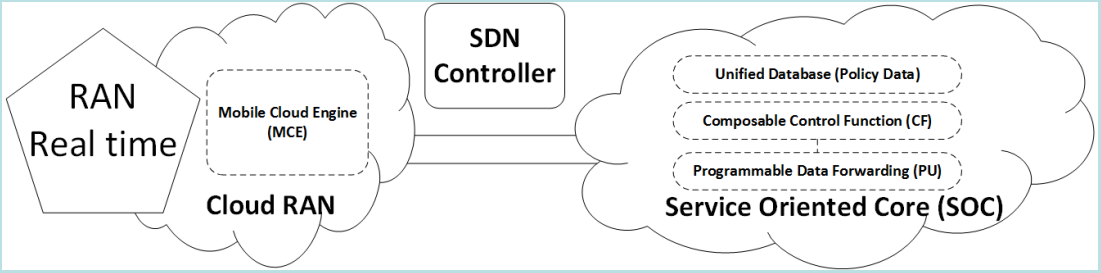
Service-Driven 5G Architecture

- Aims to flexibly and efficiently meet diversified mobile service requirements
- 5G comprehensively cloudifies access, transport, and core networks
  - Cloud adoption allows for better support for diversified 5G services
- enables the key technologies of E2E network slicing
- on-demand deployment of service anchors
- component-based network functions



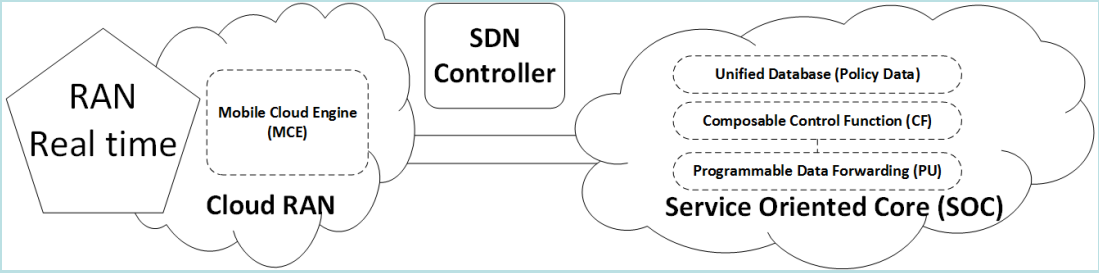
Service-Driven 5G Architecture

- CloudRAN consists of sites and mobile cloud engines
  - coordinates multiple services
  - operating on different standards
  - in various site types for RAN real time resources that require a number of computing resources
  - Multi-connectivity is introduced to allow on-demand network deployment for RAN non-real time resources



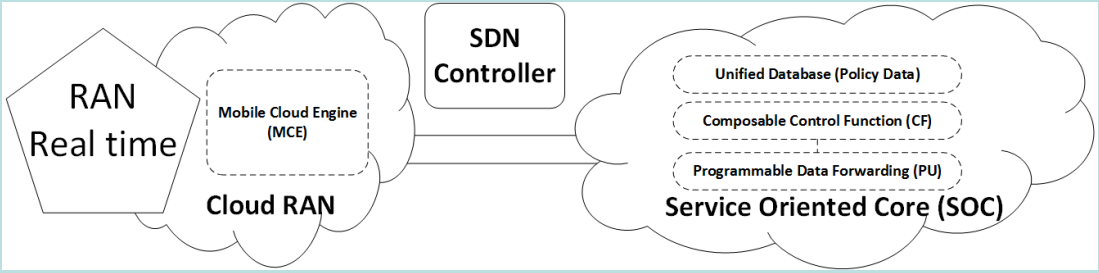
Service-Driven 5G Architecture

- The transport network consists of SDN controllers and underlying forwarding nodes.
  - SDN controllers generate a series of specific data forwarding paths based on network topology and service requirements.
  - The enabling plane abstracts and analyses network capabilities to implement network optimization or open network capabilities in the form of API (Application Programming Interface)



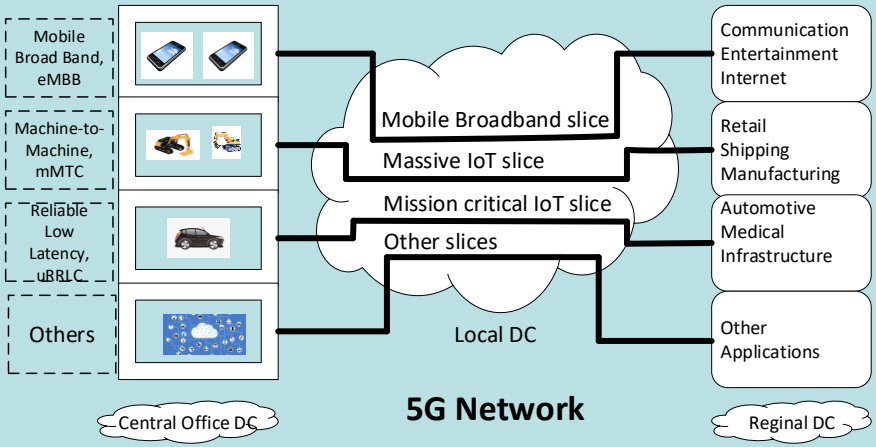
Service-Driven 5G Architecture

- Service oriented core
  - Networks implement policy control using dynamic policy, semi-static user, and static network data stored in the unified database
- Component-based control planes and programmable user planes
  - allow for network function orchestration to ensure that networks can select corresponding control-plane or user-plane functions according to different service requirements



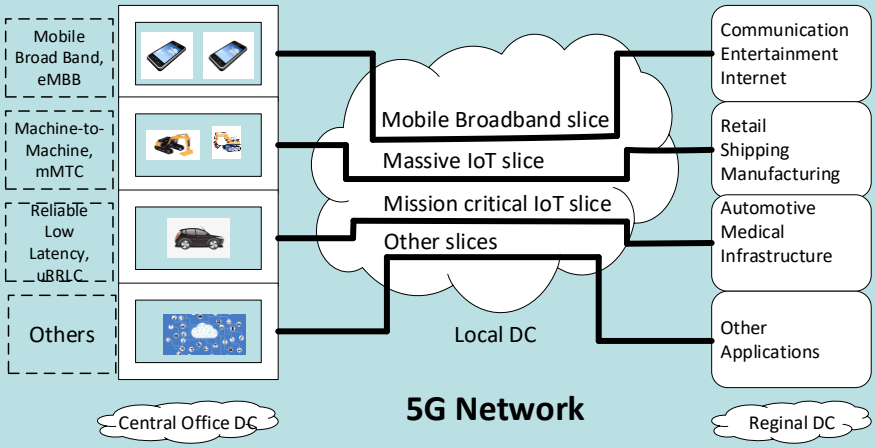
5G End to End Network Slicing

- A single physical network will be sliced into multiple virtual networks that can support different radio access networks (RANs)
- Different service types running across a single RAN



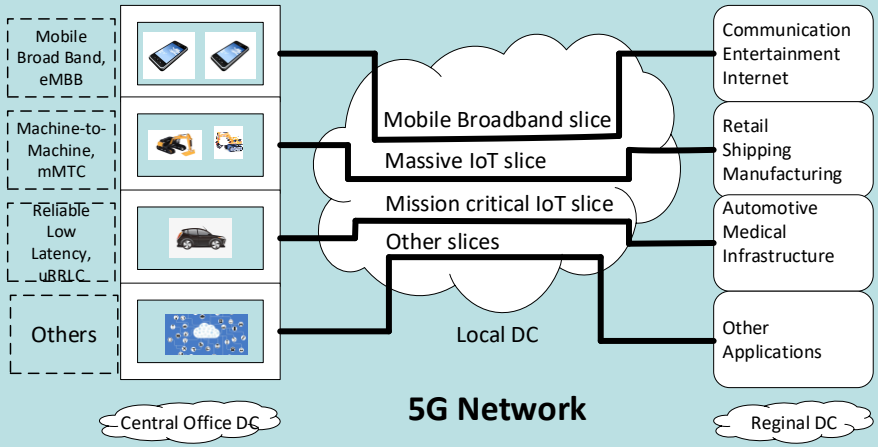
5G End to End Network Slicing

- Benefits
  - 5G network slicing enables service providers to build virtual end-to-end networks tailored to application requirements
  - Network slicing will help to address the cost, efficiency, and flexibility requirements imposed by future
  - Two closely related network virtualization technologies: SDN and NFV allow far better network flexibility through the partitioning of network architectures into virtual elements.



5G End to End Network Slicing

- Based on Network Functions Virtualization, NFV and Software Define Network, SDN, physical infrastructure of the network architecture consists of sites and three-layer DCs



5G Frequency Spectrums

- Below 3GHz
  - particularly useful for coverage especially indoor and in rural areas
- Spectrum between 3 to 6 GHz
  - able to offer a mixture of coverage and capacity.
  - need to use carrier aggregation to support the highest potential data rate of 5G.
  - most of the major commercial 5G launches are expected in this spectrum range.
- Above 24 GHz spectrum, the mmWaves
  - particularly useful to support very high data rates and short-range connectivity.

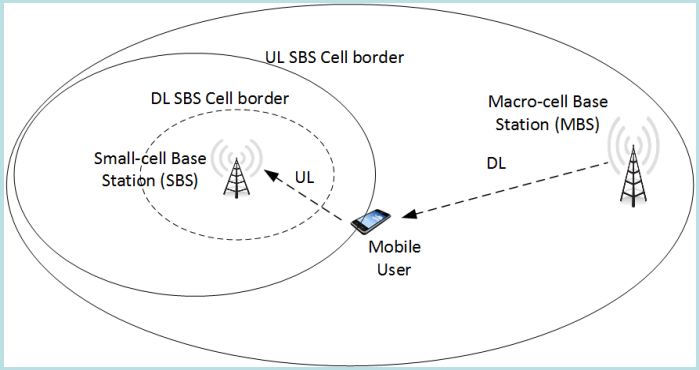
5G Frequency Spectrums

- Some of the importance characteristics of 5G Spectrum

Spectrum range	Bands	Cell Range/Coverage	Date Rate	Bandwidth
< 3 GHz	600 MHz 700 MHz 900 MHz 1800 MHz	Deep indoor >1 km	~100 Mbps	FDD 2x10 MHz
3 – 6 GHz	3.4-3.6 GHz 3.6-3.8 GHz 4.5-4.9 GHz	Same grid as LTE1800 ~1 km	~1 Gbps	TDD <100 MHz
mmWaves > 24 GHz	26 GHz 28 GHz 39 GHz	Hot spots Line of sight 100 m	~10 Gbps	TDD <1 GHz

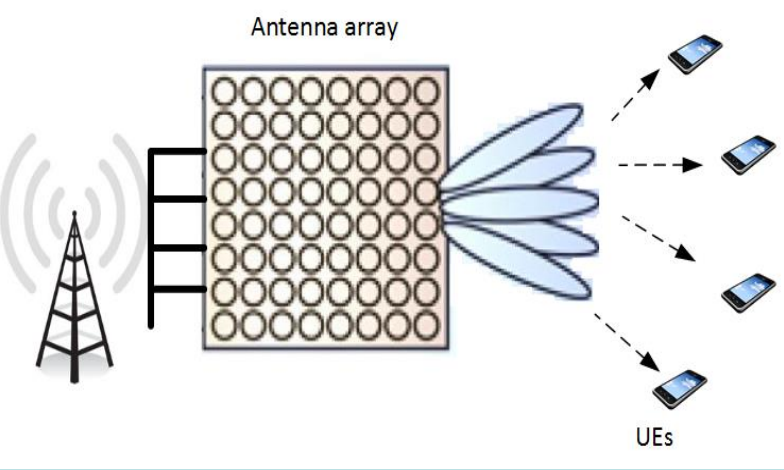
UL/DL decoupling

- To separate uplink and downlink of 5G networks onto different frequency bands
  - to configure a low frequency band for the uplink to resolve the issue of limited uplink coverage
- Example,
  - the mobile user prefers to connect to the macro-cell base station, MBS in DL and small-cell base station, SBS in UL
    - the user to reduce their transmission power since it associates with the nearest BS in the UL direction
    - reduce the interference level at the BS as well as



Massive Beamforming in 5G

- Pack more elements into a smaller antenna at higher carrier frequency
- The beams get narrower with more antenna elements
- Steer the transmission towards the intended receiver
- maximize the received signal energy at the mobile in a certain direction
- Improve the coverage significantly



Massive MIMO

- Provide user-centric dynamic narrow beams for the antenna pattern
- Large antenna arrays to spatially multiplex many terminals
- Improving coverage and reducing inter-cell interference
  - Static beams
  - Dynamic beams

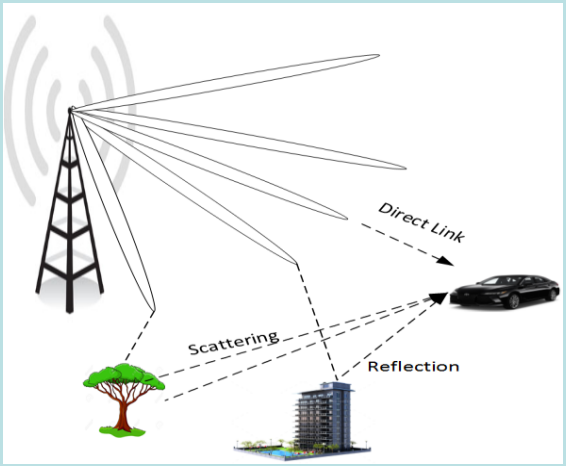
Massive MIMO

Static beams

- Beams can be generated in advance based on the antenna structure and beamforming weight to facilitate planning and simulation

Dynamic beams

- User-centric dynamic beams are formed based on multiple paths and measurement results, which is similar to onsite scenarios



5G Deployment Option

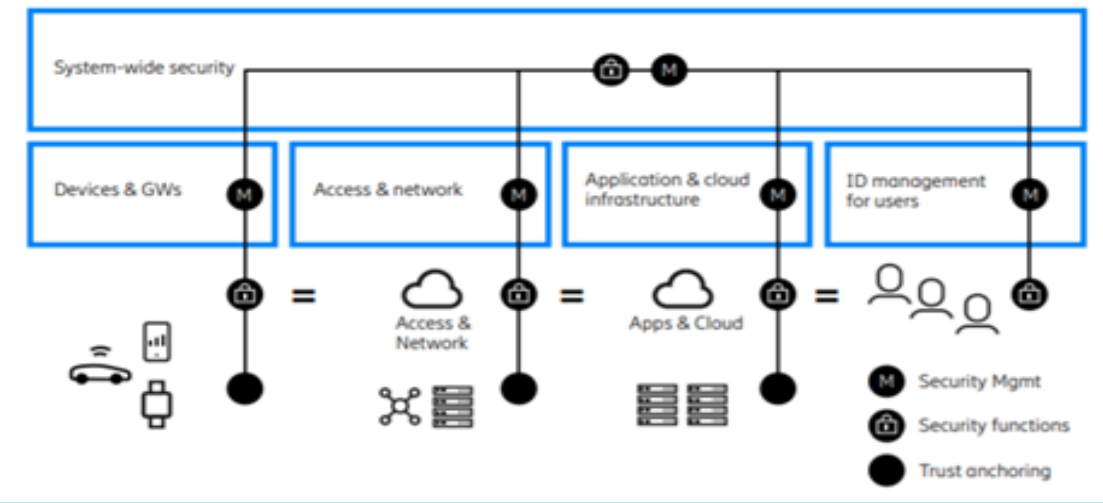
- Standalone (SA) & Non-standalone (NSA)

	Standalone (SA)	Non-standalone (NSA)*
NR radio cells	Directly used by 5G device for control and user planes	Used as a secondary carrier, under the control of LTE base station
Core choice	5G next-gen core (5GNC) which may also anchor IRAT mobility with LTE	4G EPC or 5G next-gen core (5GNC)
Operator perspective	Simple, high performance overlay	Leverages existing 4G deployments
Network vendor perspective	Independent RAN product	Requires tight interworking with LTE
End user experience	Peak bitrate set by NR Dedicated Low Latency transport	Peak bitrate is sum of LTE and NR Latency impacted if routed via LTE

5G Security

System-wide security (horizontal security)

- Network level
- Slicing
- Application level security
- Confidentiality and integrity protection
- Interconnect Service Base Architecture, (SBA)



5G Security

5G function element deployments (vertical security)

- Network Function Virtualization, (NFV)
- Distributed clouds

Comparison between LTE and 5G

Features	LTE	5G
Data Rate	1 Gbps	20 Gbps
Latency	10 msec	1 msec
Spectral efficiency	3 bps/cell/Hz	10 bps/cell/Hz
Energy efficiency	200 Wh/TB	1 kWh/TB
Lower IoT power	100 microWh per tx	10 micorWh per tx

5G Applications

	Category	Applications
Consumers	Mobile Broadband	Smartphones in dense urban area Corporate mobile office
	Fixed Wireless Access	5G for residential homes Wireless SOHO/VPN
	Event experience	Immersive VR360 AR gaming
	In-Vehicle Entertainment	Private cars Public transport
Industries	Critical automation	Collaborative robots/drones Electrical grid tele-protection
	Tele-operation	Video-base remote control Video w/haptic remote control
	Highly interactive AR	Co-present Mixed Reality 360° volumetric video AR/MR
	Mass sensor arrays	Agriculture field sensors Smart city sensors & meters

5G Applications

5G Use Cases

- Broadband and media everywhere
- Smart vehicles and transport
- Critical services and infrastructure control
- Critical control of remote devices
- Human machine interaction
- Sensors networks

https://www.ericsson.com/en/5g/use-cases
https://www.ericsson.com/assets/local/5g/5g-use-cases-ericsson.pdf

5G Applications

5G Use Cases, Vertical industries

- Manufacturing
- Healthcare
- Media and Entertainment
- Financial Services
- Public Safety
- Automotive
- Public Transport
- Energy Utilities

https://www.huawei.com/minisite/5g/img/gsa-5g-network-slicing-for-vertical-industries.pdf