Formación Profesional en CePETel 2022

Desde la Secretaria Técnica del Sindicato CePETel convocamos a participar en el siguiente curso de formación profesional:

Redes 5G - Nivel Avanzado

Clases: 6 de 3hs c/u de 18:00 a 21:00 hs.
Días que se cursa: los días jueves,7, 21 y 28 de abril; y 5, 12 y 19 de mayo.
Modalidad: a distancia (requiere conectarse a la plataforma Zoom en los días y horarios indicados precedentemente).
Docente: José Luis Pellegrino

La capacitación es:

- **Sin cargo para afiliados y su grupo familiar directo.**
- **Sin cargo para encuadrados con convenio CePETel.**
- **Con cargo al universo no contemplado en los anteriores.**

Informes: enviar correo a tecnico@cepetel.org.ar

Inscripción (hasta el 4 de abril): ingresar al formulario (se recomienda realizar el registro por medio de una cuenta de correo personal y ***no utilizar dispositivos de la empresa para acceder al link*****).**

https://forms.gle/N9bJNYs6g7Rf86Xs9

Objetivos

Este curso permitirá a aquellas personas que posean conocimientos básicos de las Redes 5G adquiridos en el curso “Redes 5G – Nivel Básico”; conocer los aspectos avanzados de las Redes 5G.

Temario:

MODULO 1
Arquitectura de la red de Red de Acceso.
Protocolos: capa física, MAC, RLC, PDCP, capas altas.
Ancho de banda asociado a cada capa.
Modelo de Centralización y de Distribución.
CPRI.

Glosario:
MAC: Medium Access Control
RLC: Radio Link Control

Ing. Daniel Herrero – Secretario Técnico – CDC

PDCP: Packet Data Convergence Protocol
CPRI: Common Public Radio Interface

MODULO 2
Arquitectura del Núcleo en Redes SA
SBA y protocolos de Core
Concepto de Slicing
Entidades, Interfaces, Protocolos.
Overlay 5GC con EPC

Glosario:
SA: Stand Alone
5GC: Core de 5G
EPC: Evolved Packet Core

MODULO 3
La red de transporte en 5G.
Requerimientos de ancho de banda.
Requerimientos de latencia. TSN.
Desagregación de la Red de Acceso.

Glosario:
TSN: Time Sensitive Networks

MODULO 4
Open RAN
Arquitectura.
Modelo
Casos y desafíos

Glosario:
RAN: Radio Access Network

MODULO 5
Automatización
SDN
SON
RIC
5G Signalling
NWDAF

Glosario:
SDN: Software defindedNetworking
SON: SelfOptimization Network
RIC: RAN IntelligenceController
NWDAF: network data analyticsfunction

Acerca deldocente

José Luis Pellegrino es Ingeniero en Electrónica Universidad Nacional de La Plata (especialista en Telecomunicaciones), contando con más de 20 años de experiencia laboral. Es experto en redes fijas y móviles,y posee un amplio conocimiento sobre diferentes tecnologías tales como Conmutación C.S Y P.S, NGN, redes y protocolos de señalización S7 (ISUP/MAP/INAP) y señaización IP:H.248, SIP, Diameter, así como también en redes y arquitecturas IMS, C.S, SBC, P.S, LTE, CSFB, mVoLTE, fVoLTE, WiFi, WiFiCalling, WRTC.En el Sindicato Cepetel dictó el curso CORE IMS en el año 2021, mientras que en el 2021 hizo lo propio con Redes 5 G Nivel Inicial.

Ing. Daniel Herrero – Secretario Técnico – CDC

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REDES DE QUINTA GENERACIÓN
Curso Nivel 2
Módulo 1

CePETel

Prof. José Luis Pellegrino

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MODULO 4
Open RAN
Arquitectura.
Modelo
Casos y desafíos

LTE & EPC

MODULO 5

5G Signalling

NWDAF Network Data Analytics Function

SEPP Seurity Edge Protection Proxy

MODULO 6

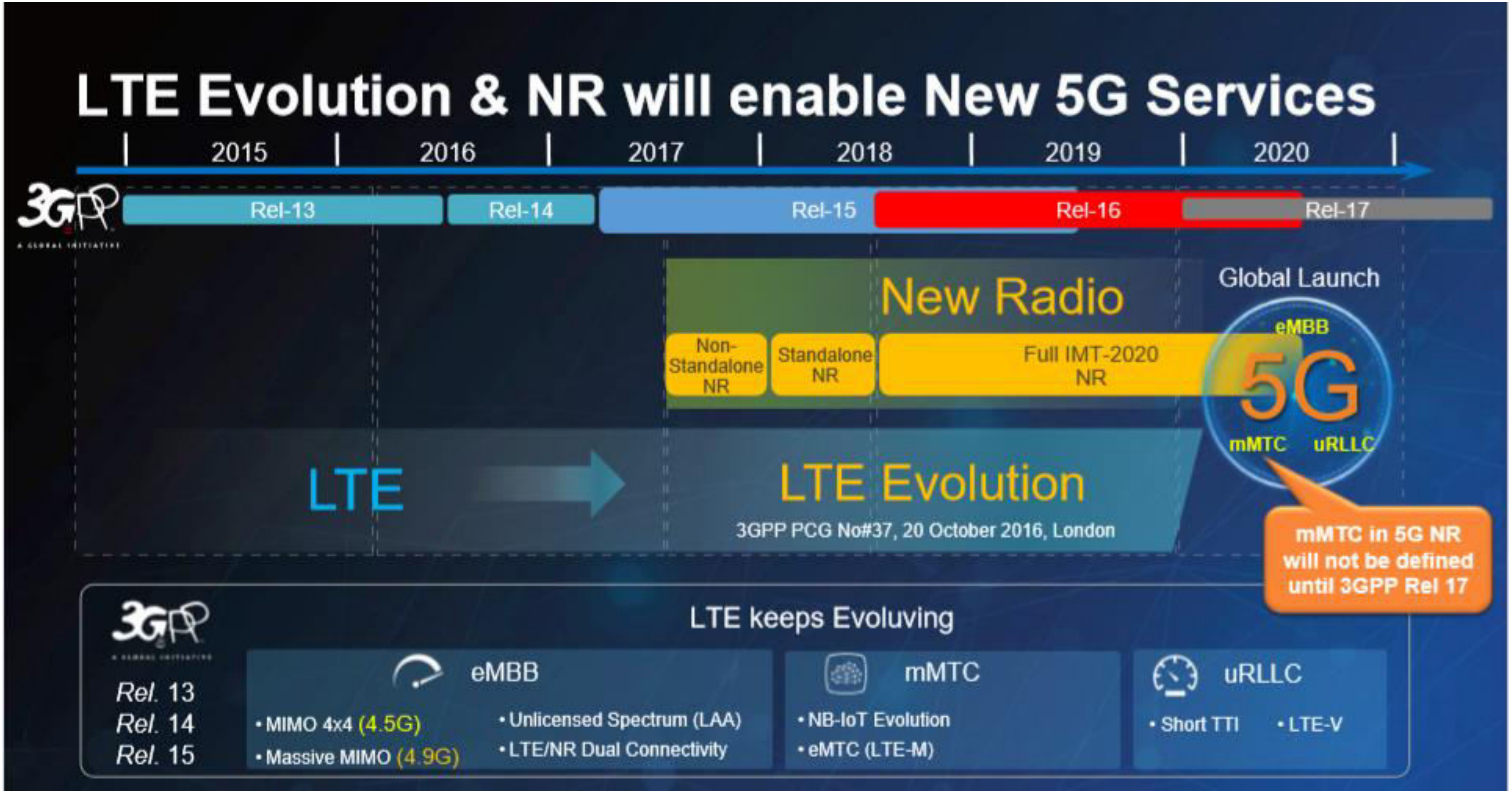
Automatización

SDN

SON

RIC

ROL DE LTE EN 5G



Fuente Huawei

PATRONES DE TRÁFICO

Water / gas meter

Periodic transmission, little data amount, no mobility, deep indoor locations with poor coverage
Low power consumption requirements

Burglar alarm

Spontaneous transmission, little data amount, no mobility
Possibly low power consumption requirements

Surveillance camera

Constant, high data rate transmission, no mobility
No power saving features needed

Fleet tracking device

Periodic and spontaneous data transmissions, polling from application server side
High mobility

Road traffic camera

Periodic transmission of small data amounts with possibly video stream when unusual activity (e.g. an accident) detected.

Patient health monitoring system

Periodic and spontaneous data transmissions, requests from server side, low delay tolerant transmission e.g. in case of sudden condition changes, medium mobility

Object tracking

Little or no device initiated transmissions, short response time requirements for server-side queries
High mobility, possibly low power consumption requirements

Remotely operated machinery, e.g. water valve

Little or no device initiated transmissions, short response time requirements for server-side queries
Low or no mobility, possibly low power consumption requirements

REQUERIMIENTOS DE 5G

The 5G system is characterised by:

- Support for multiple access technologies
- Scalable and customizable network
- Advanced Key Performance Indicators (KPIs) (availability, latency, reliability, user experienced data rates, area traffic capacity)
- Flexibility and programmability (e.g., network slicing, diverse mobility management, Network Function Virtualization)
- Resource efficiency (both user plane and control plane)
- Seamless mobility in densely populated and heterogeneous environment
- Support for real time and non-real time multimedia services and applications with advanced Quality of Experience (QoE)

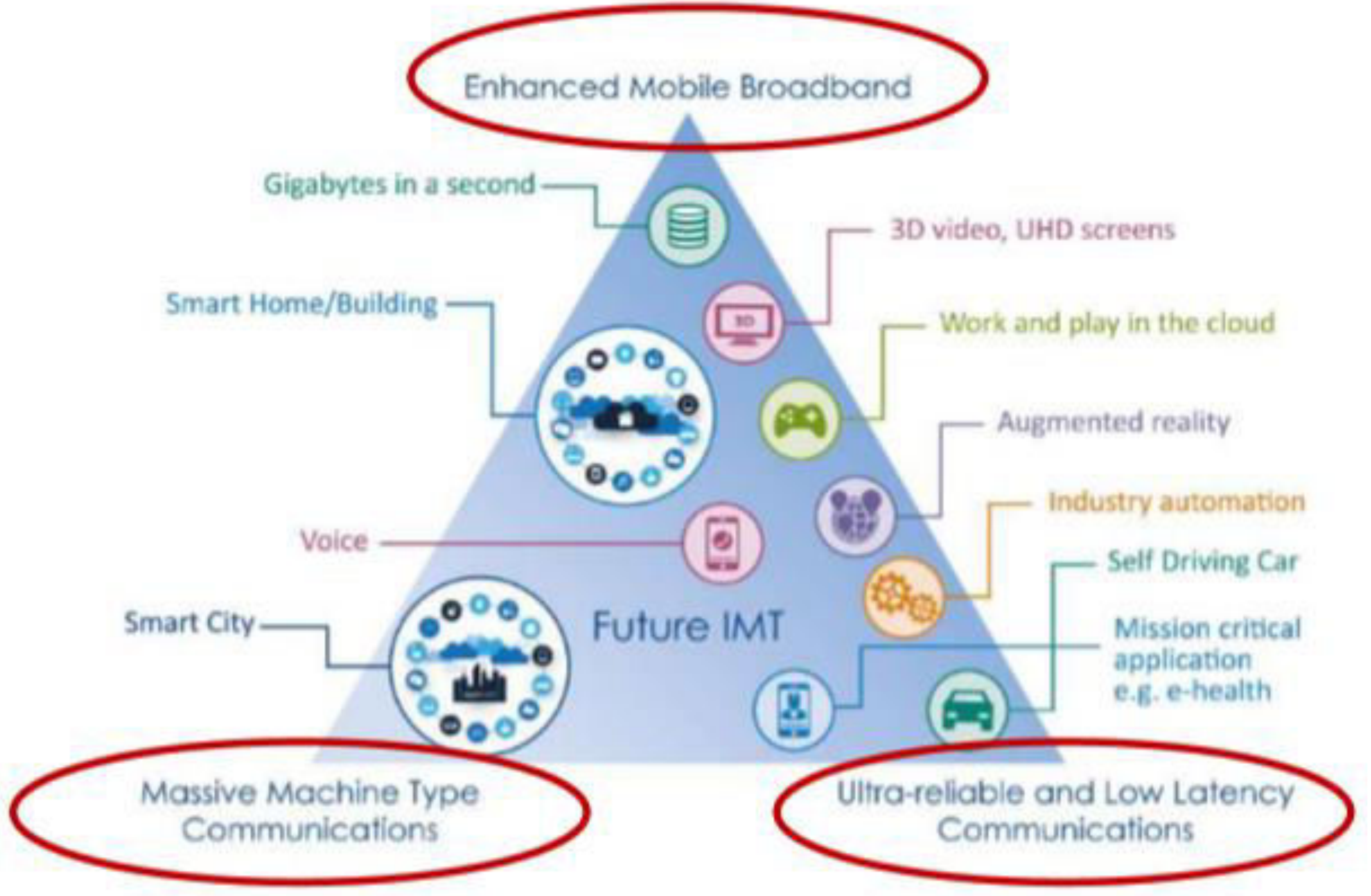
The 5G system shall support :

- The extreme long range coverage (up to 100 km) in low density areas (up to 2 user/km^2)
- A minimum user throughput of 1 Mbps on DL and 100 kbps on UL at the edge of coverage
- A minimum cell throughput capacity of 10 Mbps/cell on DL (based on an assumption of 1 GB/month/sub)
- A maximum of 400 ms E2E latency for voice services at the edge of coverage

A key feature of 5G is support for UEs with different mobility management needs. 5G will support UEs that are:

- Stationary during their entire usable life (e.g., sensors embedded in infrastructure)
- Stationary during active periods, but nomadic between activations (e.g., fixed access)
- Mobile within a constrained and well-defined space (e.g., in a factory)
- Fully mobile

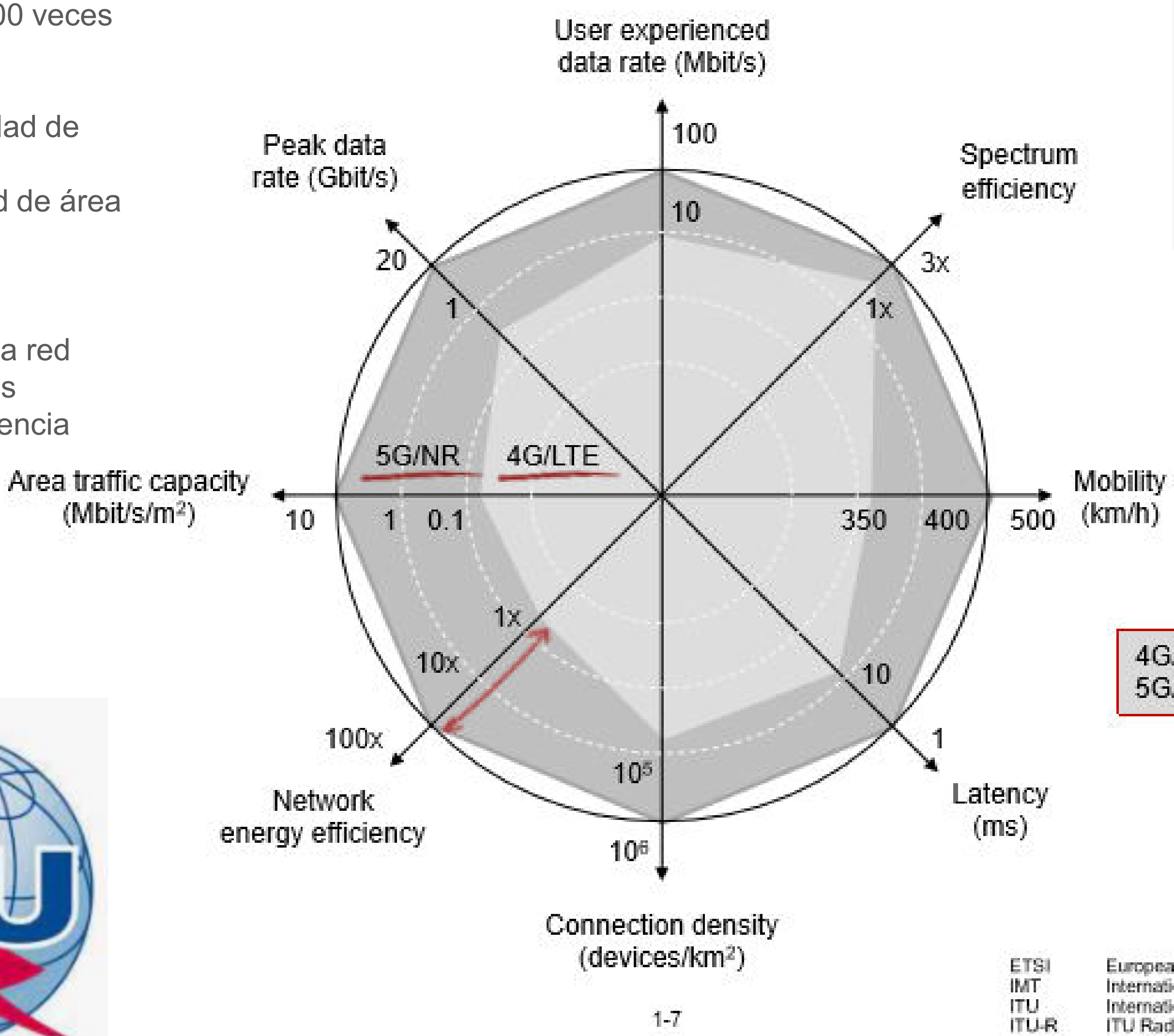
CASOS DE USO


Enhanced Mobile Broadband
Gigabytes in a second
3D video, UHD screens
Smart Home/Building
Work and play in the cloud
Augmented reality
Industry automation
Voice
Self Driving Car
Smart City
Future IMT
Mission critical application e.g. e-health
Massive Machine Type Communications
Ultra-reliable and Low Latency Communications

EXPECTARTIVAS DE ETSI Y DE ITU

- •Una tasa de datos de hasta 10Gbps - > de 10 a 100 veces mejor que las redes 4G y 4.5G
- •Latencia de 1 milisegundo
- •Una banda ancha 1000 veces más rápida por unidad de área
- •Hasta 100 dispositivos más conectados por unidad de área (en comparación con las redes 4G LTE)
- •Disponibilidad del 99.999%
- •Cobertura del 100%
- •Reducción del 90% en el consumo de energía de la red
- •Hasta 10 diez años de duración de la batería en los dispositivos IoT (Internet de las Cosas) de baja potencia

Reflexionar sobre estos indicadores

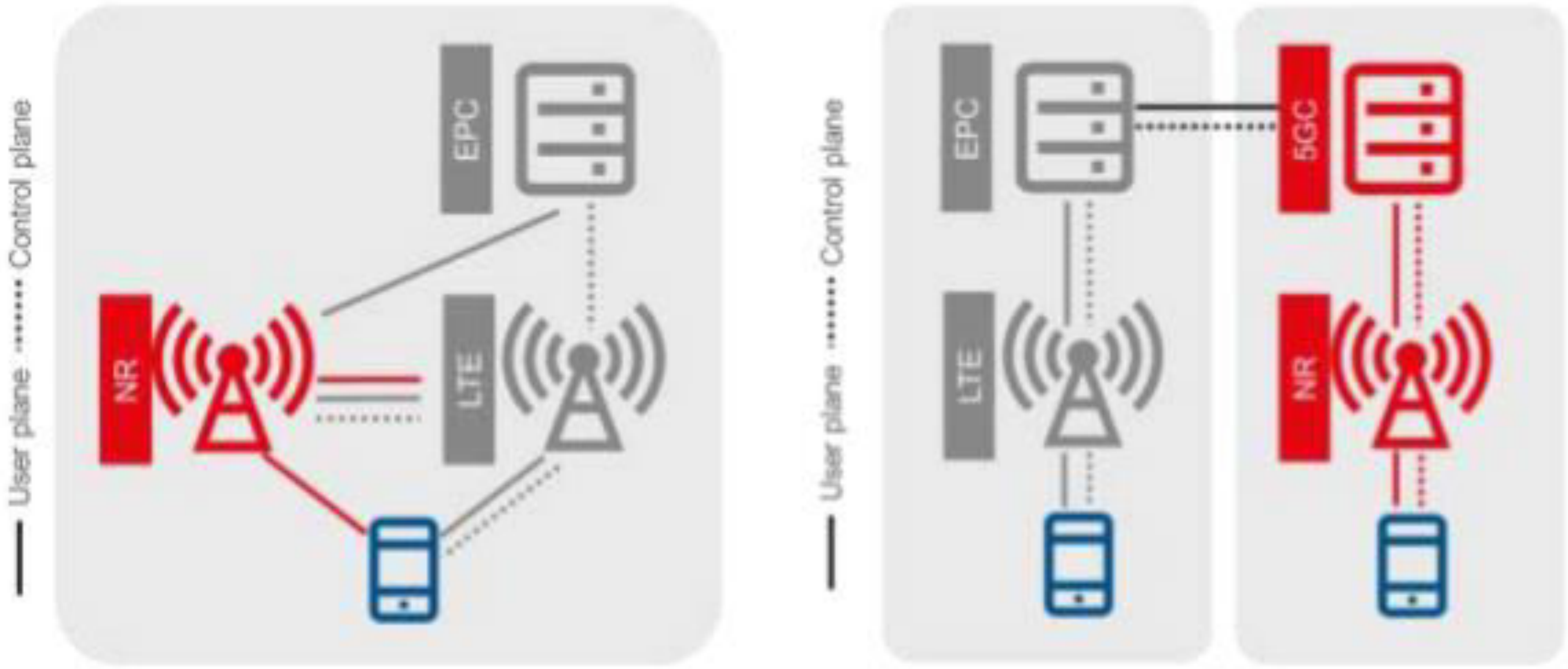


4G/LTE = "IMT Advanced"
5G/NR = "IMT-2020"

ETSI	European Telecommunications Standards Institute
IMT	International Mobile Telecommunication
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication sector

REPASO DE PREREQUISITOS

STAND ALONE Vs NON STANDALONE



Fuente: GSMA

ESPECTRO

Fuente: GSMA

Bandas S y C. Desde 2GHz a 4GHz y desde 4GHz a 8GHz respectivamente (rangos de frecuencias desde 3.4GHz a 4.2 GHz)

ESPECTRO

Fuente: GSMA

De 24GHz a 29.5GHz y de 37GHz a 43.5GHz. Alta atenuación, canal de subida MIMO y beamforming poco efectivo.
28GHz para FWA, gran capacidad, apto para hotspots y muchos otros escenarios corporativos .
Espectro disponible, metas de IMT 2020 (100 MHz, difícil)

ESPECTRO

La banda mas usada hoy es la N257 (de 28 GHz) y su subset la N261, son unos 50 dispositivos.
La banda de 26 Ghz , es mundial, hoy día son unos 20 dispositivos, pero eso va a mejorar.
La banda de 39 GHz, N260 también con varios ecosistemas.
Bandas de 41 y 47 GHz en plan de uso en Japón y US.
En Latinoamérica se prevee el uso desde 24,5 GHZ a 27 GHz (banda de 26).
Uruguay iría por la N261.

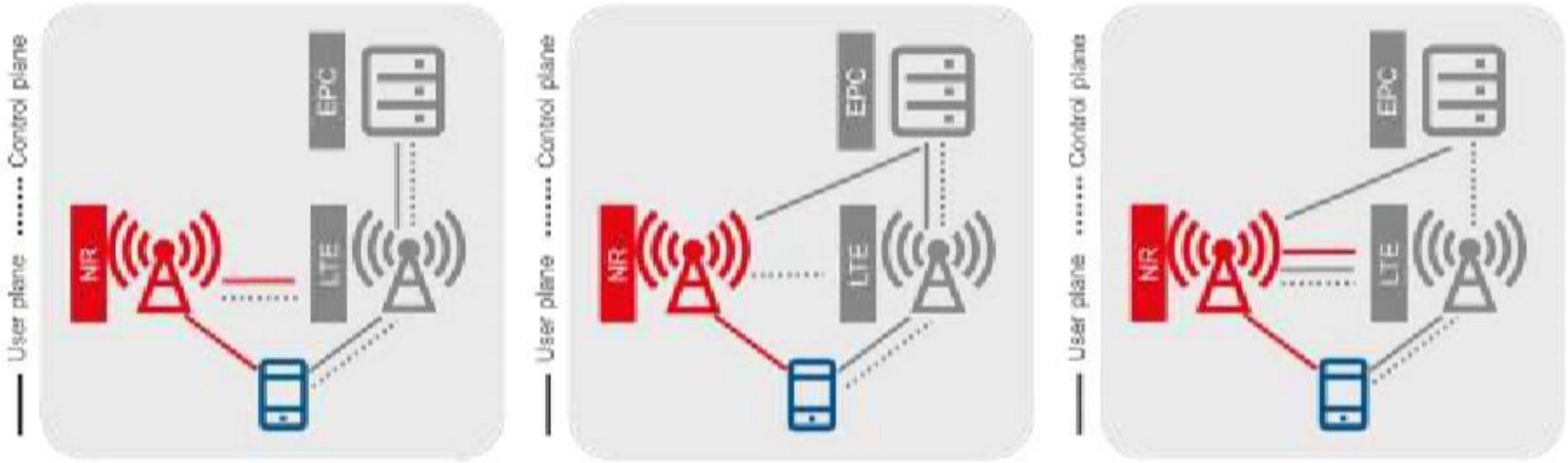
En mmW de 2 a 3 Gbps es razonable, eso es imposible en bandas medias o bajas
800 MHz a 1GHZ de ancho de banda por operador o mas aún
Ya está probada, fue el early adoption
Atención a los nuevos canales de revenue

En occidente, los niveles de radiación los mide ismir y IEEE, con protocolos similares
Ya se contemplan los niveles de radiación de 5G y 6G hasta 300 GHz.
Se definen zonas seguras (en la cercanía de la antena no se permite)
Las radiaciones en estas bandas llegan solo a la epidermis, por eso el SAR ya no se basa en la unidad de masa de cuerpo, sino de superficie (mW/cm2), pues la radiación no penetra los tejidos internos.

ESPECTRO CAPACIDAD Y COBERTURA

- Técnicas avazadas de antenas como MIMO y beamforming, en 3,5 GHz, similar cobertura que en 2GHz en DL.
- En UL MIMO y beamforming no son prácticos (UE). Si se usan las mismas bandas, en UL, la cobertura sería menor.
- Por eso se propone usar espectros bajos para el UL. *To overcome this problem it has been proposed to utilise lower band spectrum such as the 1800 MHz spectrum for the uplink data (i.e. supplementary uplink).*
- La diferencia clave entre usar CA para UL y usar la división de enlace ascendente / descendente en distintas bandas (DC), es que CA intenta mejorar el ancho de banda (por lo tanto, la capacidad) del enlace ascendente, mientras que la división de enlace ascendente / descendente se usa para extender la cobertura del UE.
- Si bien CA puede aumentar la capacidad mediante la utilización de portadoras de múltiples componentes (por ejemplo, banda de 20Mhz en 1.8GHz y banda de 20Mhz en 800Mhz), la división de enlace ascendente / enlace descendente hace que el UE use portadoras de componente diferente para el enlace ascendente (por ejemplo Banda de 20MHz en 1.8GHz) que del enlace descendente (por ejemplo, banda de 20 MHz en 3,5 GHz).
- En general, es posible utilizar CA junto con DC. Es decir, los CC se pueden agregar (en E-UTRA y / o NR) y luego se aplica DC

ESPECTRO CAPACIDAD Y COBERTURA



Fuente: GSMA

Identificar cada una de las figuras con una opción NSA

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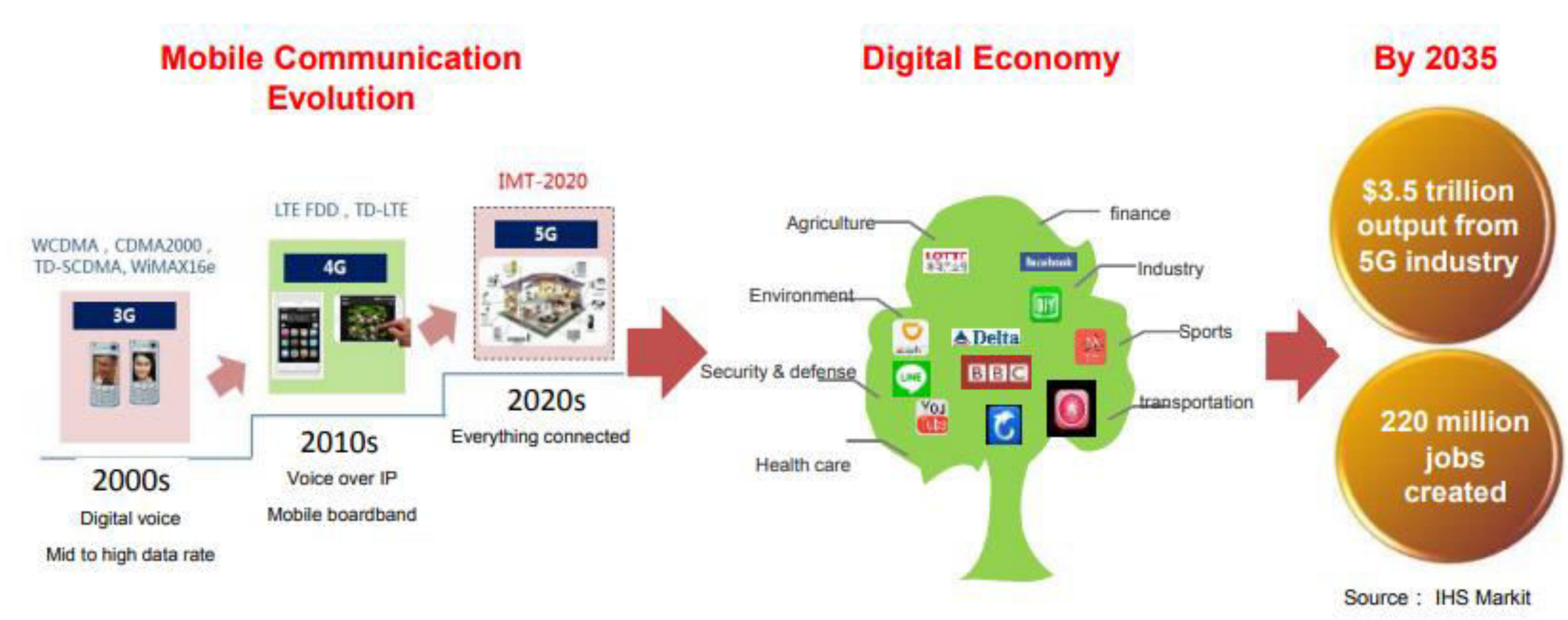
ESPECTRO: REQUERIMIENTOS PARA 5G

Crecimiento de la economía, un driver para las comunicaciones móviles

The fast-developing mobile communication drives information consumption explosion & digital economy booming, which will bring the significant economic value all over the world.



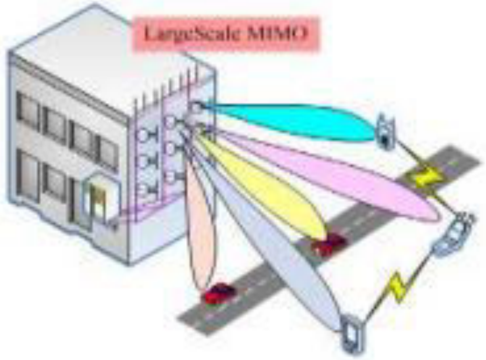
ESPECTRO: REQUERIMIENTOS PARA 5G

Todo conectado

5G realizes "Everything Connected", which brings both opportunity and challenge

Technology

Realize higher spectrum efficiency



Spectrum

Increasing shortage of frequency resource

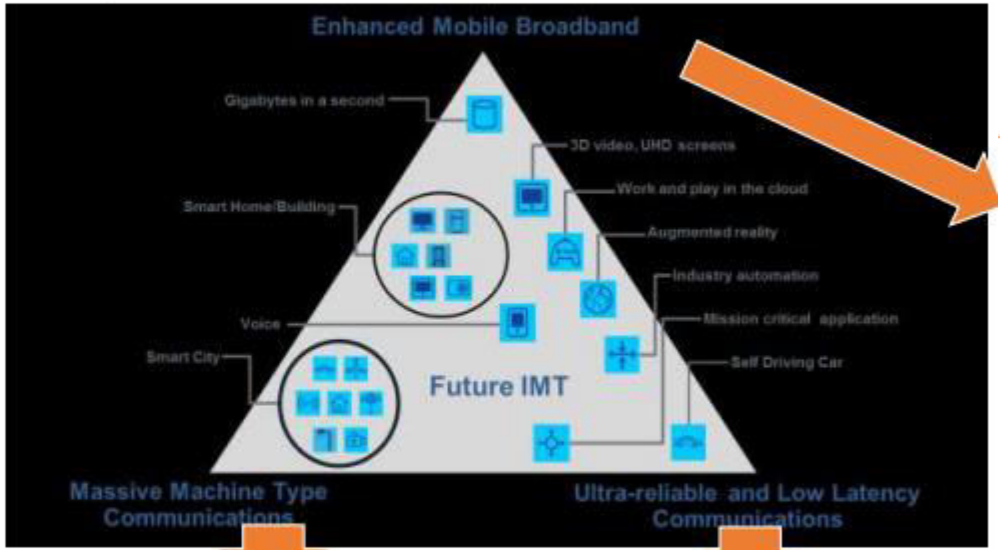
Application

Integrated with vertical industries

- **Technology**: Advanced technology required to improve spectrum efficiency
- **Spectrum**: Higher frequency band required to cope with the increasing scarcity of low-frequency band spectrum
- **Application**: Industry convergence is a global challenge. Industry developing bottlenecks like business model, laws and regulations and industry barrier need to be broken through.

ESPECTRO: REQUERIMIENTOS PARA 5G

5G Spectrum vs. Scenarios



eMBB			
Indoor hotspot	Dense urban	Rural coverage	High speed
LF and/or HF	LF and/or HF	LF	LF

M-MTC	URLLC
Urban coverage	Urban coverage
LF	LF

Fuente: ITU-T y CAICT

ESPECTRO: REQUERIMIENTOS PARA 5G

Cuanto espectro es necesario?, un ejemplo

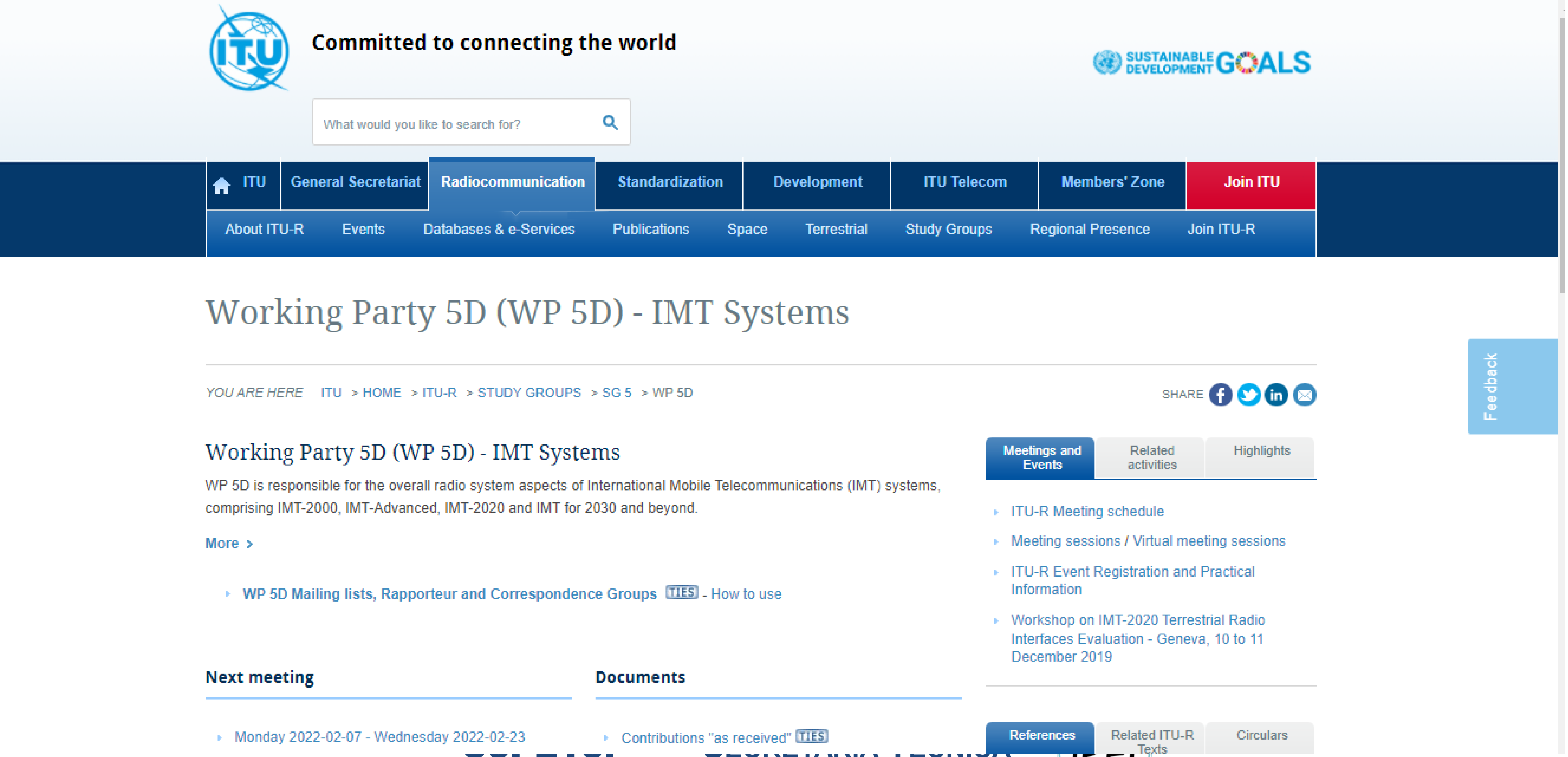
Spectrum needs of IMT-2020 by technical performance-based approach in WP5D.

Scenarios	Indoor	Dense Urban		Urban Marco
		Micro	Macro	
Frequency Bands Range	24.25-86GHz	24.25-43.5GHz	<6GHz	<6GHz

Deployment Scenarios	Macro	Micro	Indoor
Total spectrum needs for below 6GHz	**802 - 1090 MHz**	—	—
Total spectrum needs for 24.25-86 GHz	—	**15 - 20 GHz**	
Spectrum needs for 24.25-43.5 GHz	—	5.3 - 7.58 GHz	5.3 - 7.58 GHz
Spectrum needs for 45.5-86 GHz	—	—	9.7 - 12.42 GHz

Fuente: ITU-T y CAICT

Rol de la ITU (IMT) en 5G y nuevas generaciones



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Working Party 5D (WP 5D) - IMT Systems

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Working Party 5D (WP 5D) - IMT Systems

WP 5D is responsible for the overall radio system aspects of International Mobile Telecommunications (IMT) systems, comprising IMT-2000, IMT-Advanced, IMT-2020 and IMT for 2030 and beyond.

More >

- WP 5D Mailing lists, Rapporteur and Correspondence Groups TIES - How to use

Next meeting

- Monday 2022-02-07 - Wednesday 2022-02-23

Documents

- Contributions "as received" TIES

Meetings and Events | Related activities | Highlights

- ITU-R Meeting schedule
- Meeting sessions / Virtual meeting sessions
- ITU-R Event Registration and Practical Information
- Workshop on IMT-2020 Terrestrial Radio Interfaces Evaluation - Geneva, 10 to 11 December 2019

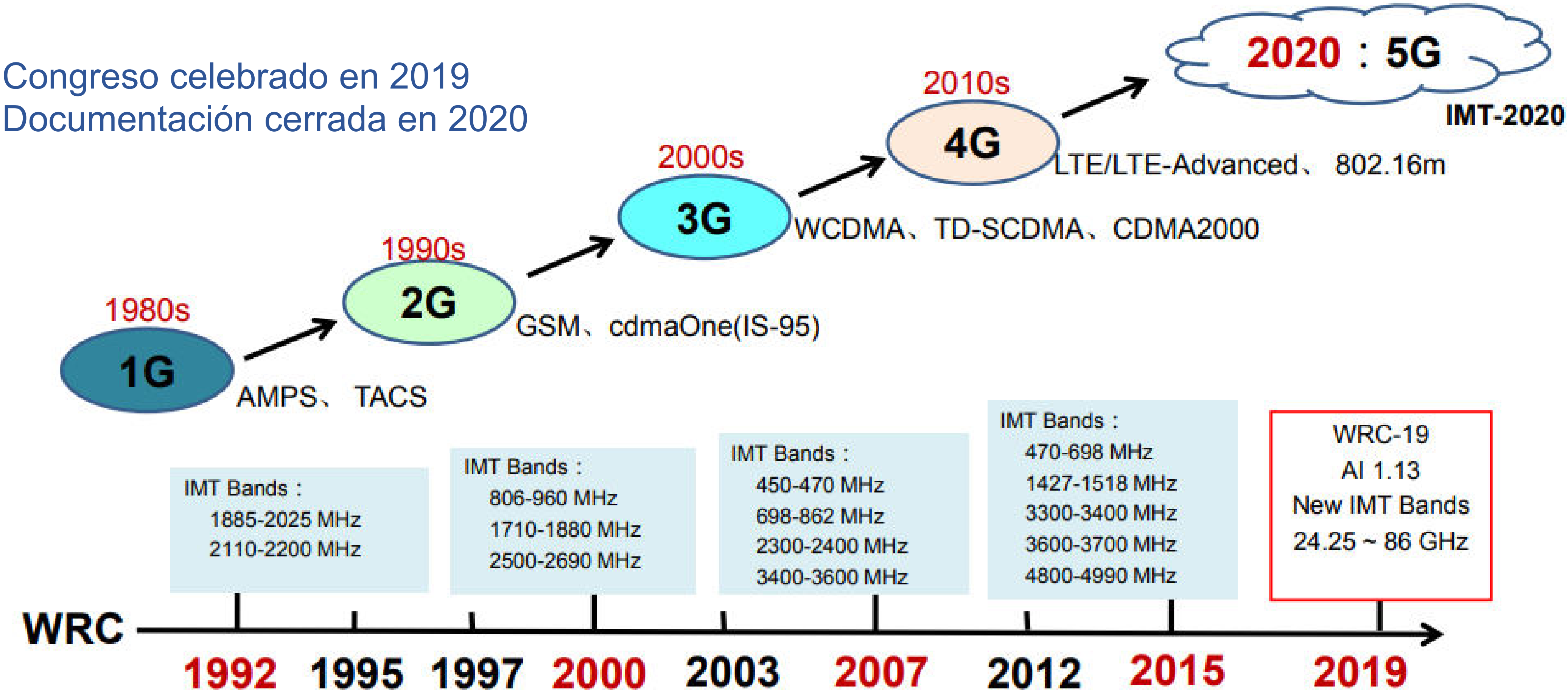
References | Related ITU-R Texts | Circulars

Feedback

ESPECTRO: REQUERIMIENTOS PARA 5G

Nuevas bandas IMT en WRC

- Congreso celebrado en 2019
- Documentación cerrada en 2020



Fuente: ITU-T y CAICT

ESPECTRO: REQUERIMIENTOS PARA 5G

Nuevas bandas IMT en WRC

World Radiocommunication Conference 2019 (WRC-19): ***additional radio-frequency bands*** for International Mobile Telecommunications (IMT), which will facilitate the development of fifth-generation (5G) mobile networks.

5G: to connect people, things, data, applications, transport systems and cities in smart, networked communication environments. It will transport a huge amount of data much faster, reliably connect an extremely large number of devices and process very high volumes of data with minimal delay.

5G technologies are expected to support applications such as smart homes and buildings, smart cities, 3D video, work and play in the cloud, remote medical services, virtual and augmented reality, and massive machine-to-machine communications for industry automation. 3G and 4G networks currently face challenges in supporting these services.

Additional bands identified to enable 5G deployment

While identifying the frequency bands **24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71** GHz for the deployment of 5G networks, WRC-19 also took measures to ensure an appropriate protection of the Earth Exploration Satellite Services, including meteorological and other passive services in adjacent bands.

In total, 17.25 GHz of spectrum has been identified for IMT by the Conference, in comparison with 1.9 GHz of bandwidth available before WRC-19. Out of this number, 14.75 GHz of spectrum has been harmonized worldwide, reaching 85% of global harmonization.

Fuente: ITU-T

ESPECTRO: REQUERIMIENTOS PARA 5G

Nuevas bandas IMT en WRC

Below 6GHz

Bands(MHz)
450-470
698-960
1 710-2 025
2 110-2 200
2 300-2 400
2 500-2 690
3 400-3 600
WRC-15 Bands (470-698、1427-1518、3300-3400、3600-3700、4800-4990)

Above 6GHz

AI 1.13,New IMT Bands(24.25 ~ 86 GHz) :

- 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and
- 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

Fuente: ITU-T

ESPECTRO: REQUERIMIENTOS PARA 5G

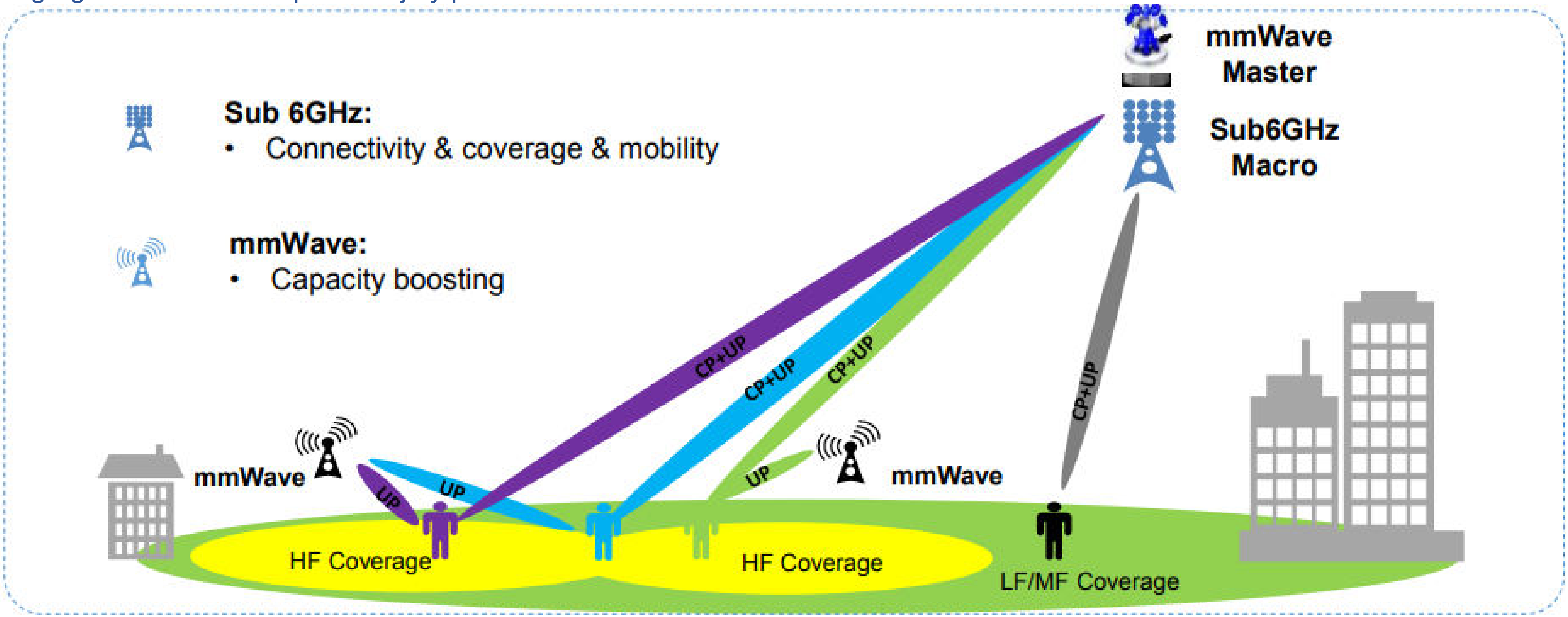
Panorama LTE en el mundo

Fuente: ITU-T

ESPECTRO: REQUERIMIENTOS PARA 5G

Escenarios para despliegue de eMBB

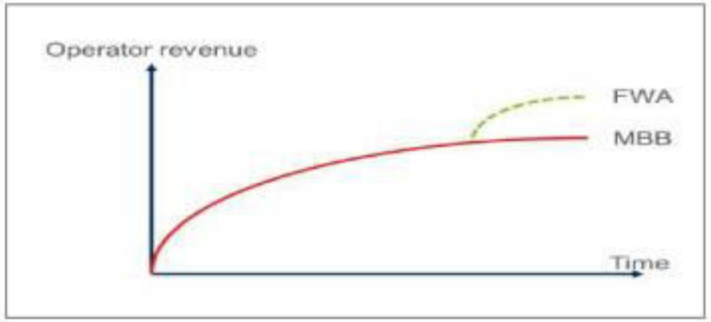
Para hacer un despliegue comercial de eMBB con éxito:
Agregar bandas de frecuencias armonizadas y garantizar áreas de cobertura contínua.
Agregación de bandas por debajo y por encima de 6 GHz

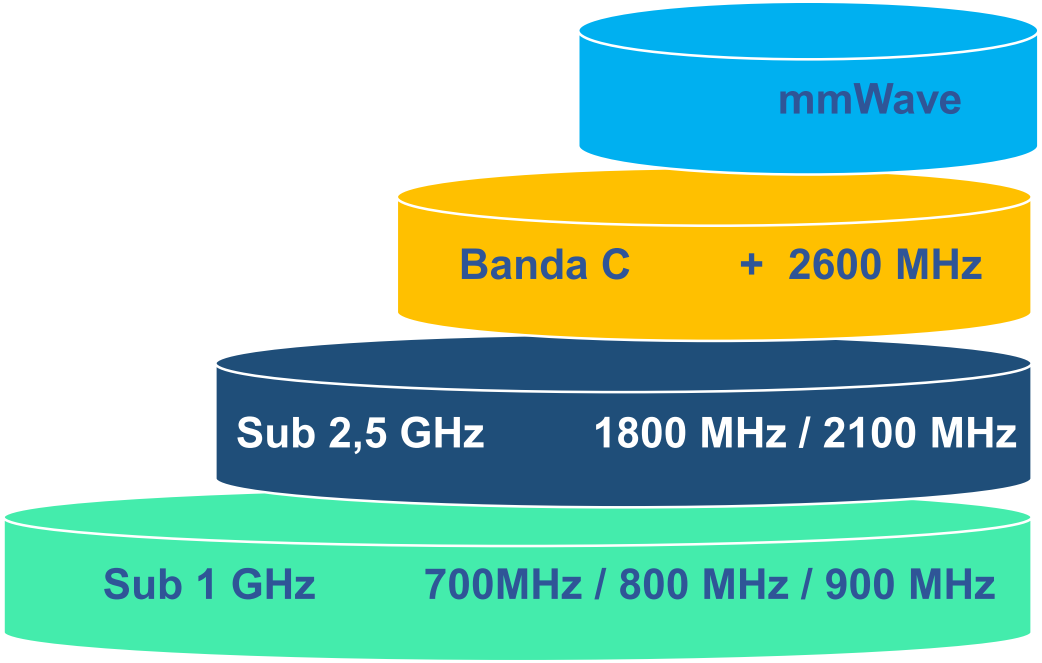


Fuente: ITU-T

ESPECTRO: REQUERIMIENTOS PARA 5G

Uso coordinado de diferentes bandas





Incremento de capacidad
- Hotspot eMBB
- Fixed wireless Access (FWA)

Espectro central para 5G
- Capacity & General coverage &mobility

Capacidad
- Complement

Aseguramiento de la cobertura
- Seamless coverage
- IoT

Fuente: ITU-T

ESPECTRO: REQUERIMIENTOS PARA 5G

Spectrum Requirement towards 5G

- Low and middle frequency bands (below 6GHz) are core bands for 5G system, which enables seamless wide area coverage capability and also applies to internet of things scenarios.
- High frequency bands (above 6GHz) are key supplemental bands for 5G system, which enables high capacity for the system and backhaul.
- Global harmonization under the study in ITU WRC-19 AI.1.13 is important, the administrations are currently focus on compatibility studies in 26GHz and 39GHz.
- International cooperation is important to promote global and regional harmonization of 5G spectrum.

Fuente: ITU-T

NSA –IMPACTO EN EPC

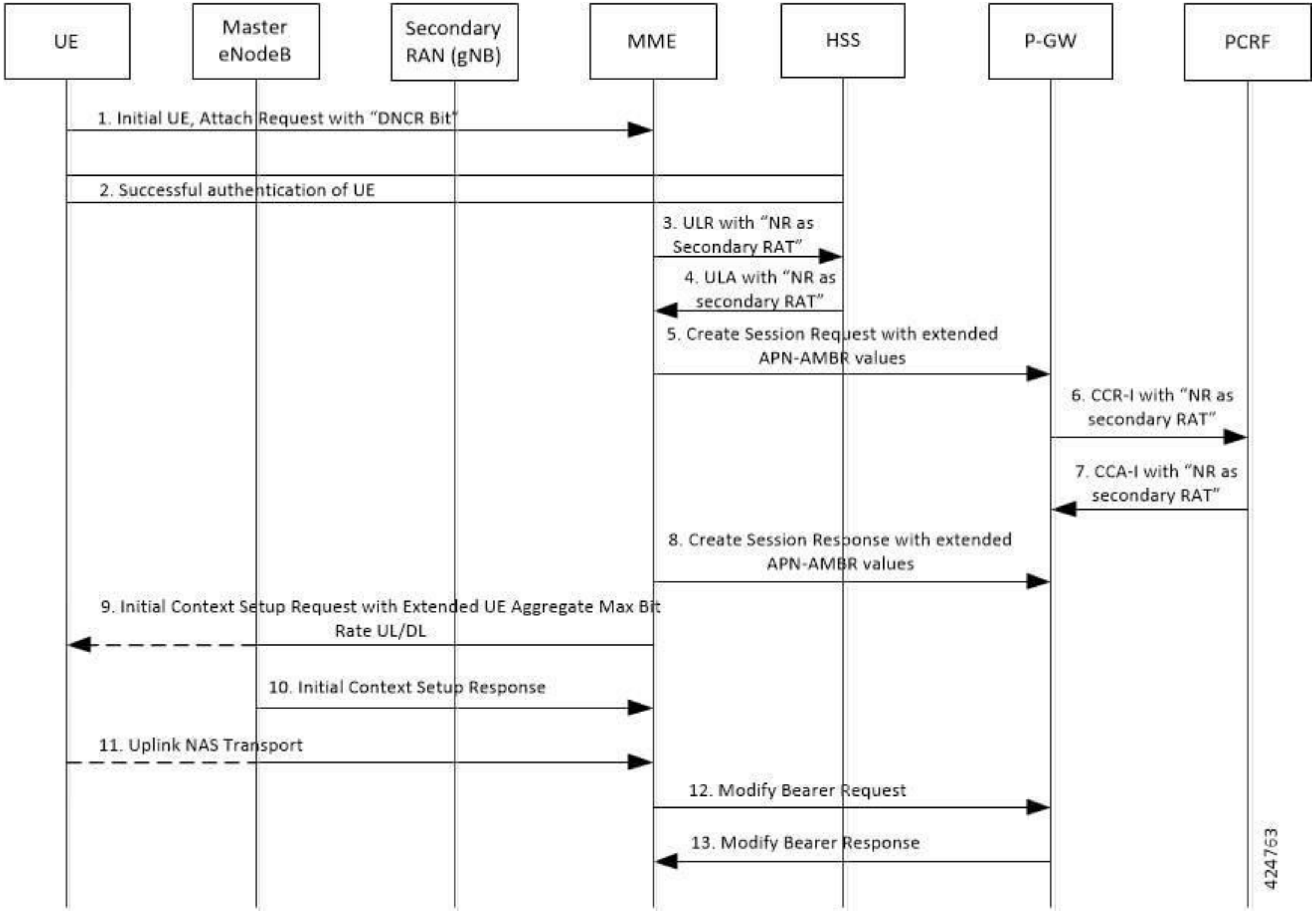
MME	• Support high bandwidth with extended QoS • Support 5G subscription access control (DCNR, Secondary RAT) • Support reporting Secondary RAT traffic • Support adding the DNS FQDN information with the NC-NR tag and querying the NSA SAE-GW information
DNS	• Match the DNS FQDN with the NC-NR tag and return the NSA SAE-GW information (no upgrade requirement)
SGw/PGw	• Support high bandwidth with extended QoS • Support 5G subscription access control (DCNR, Secondary RAT) • Support reporting Secondary RAT traffic

Fuente GSMA

NSA –IMPACTO EN EPC

CG/OCS	• CDR supports high bandwidth with extended Qos field portability • CDR supports Secondary RAT field portability • CDR adds 5G traffic report Secondary RAT Usage Reports HSS
HSS	• ARD access restriction data adds 5G NR access restriction • AMBR maximum guaranteed bandwidth adds the maximum uplink/downlink bandwidth • Extended-Max-Requested-BW-UL • Extended-Max-Requested-BW-DL
PCRF	• A new QoS extended bandwidth AVP is added to the Gx interface: • Extended-Max-Requested-BW-DL and Extended-Max-Requested-BW-UL AVP • Extended-GBR-DL and Extended-GBR-UL AVP • Extended-APN-AMBR-DL and Extended-APN-AMBR-UL AVP

NSA – SEÑALIZACIÓN



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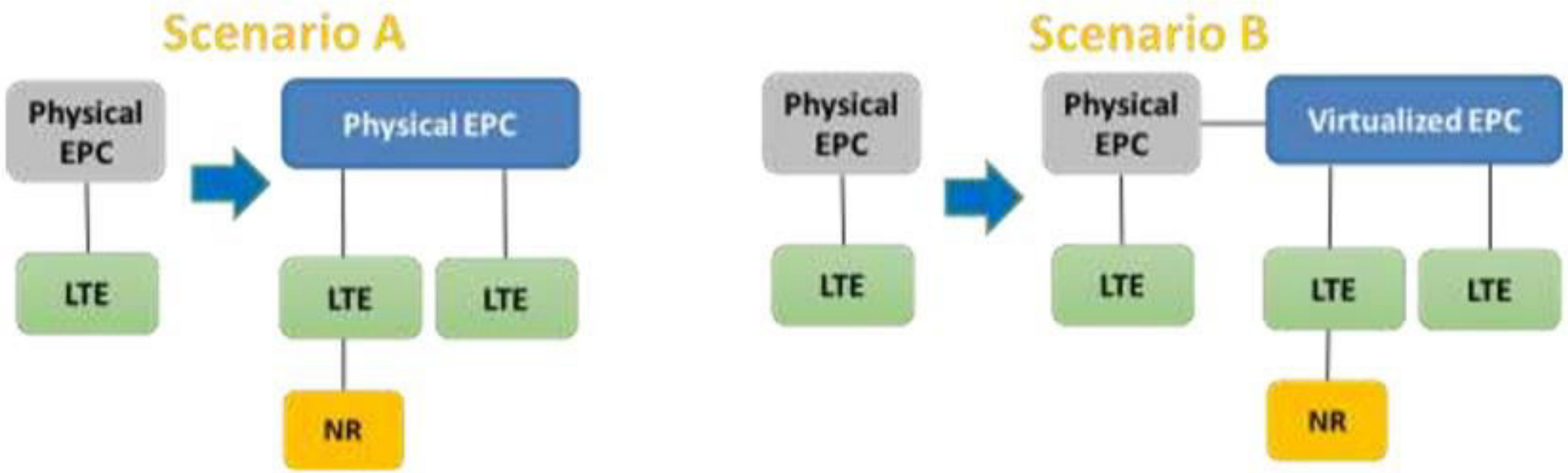
MIGRACIÓN DEL CORE



Scenario A:
Physical EPC is upgraded to support NSA.
Capacity expansion is based on physical EPC.

Scenario B:
Build a new virtualized EPC network to support NSA independently.
Interoperability is made between the new virtualized EPC and the physical EPC.
Capacity expansion is based on the virtualized EPC.

Analizar los escenario A y B , ventajas y desventajas

REQUERIMIENTOS Y ESTRATEGIAS

Las consideraciones de implementación de la red 5G incluyen principalmente la planificación de la red de destino (3GPP TS 22.261), la selección masiva de MIMO, la optimización de la cobertura, especialmente en el enlace ascendente, la configuración de la sincronización del intervalo de tiempo, la estrategia NSA y SA y los pasos de implementación de la red. Planificación de la red de destino

3GPP TS 22.261

Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density
Urban	50 Mbps	25 Mbps	100 Gbps/km²	50 Gbps/km²	10 000/km²
Rural	50 Mbps	25 Mbps	1 Gbps/km²	500 Mbps/km²	100/km²
Indoor hotspot	1 Gbps	500 Mbps	15 Tbps/km²	2 Tbps/km²	250 000/km²
Dense urban	300 Mbps	50 Mbps	750 Gbps/km²	125 Gbps/km²	25 000/km²
High-speed vehicle	50 Mbps	25 Mbps	[100] Gbps/km²	[50] Gbps/km²	4 000/km²

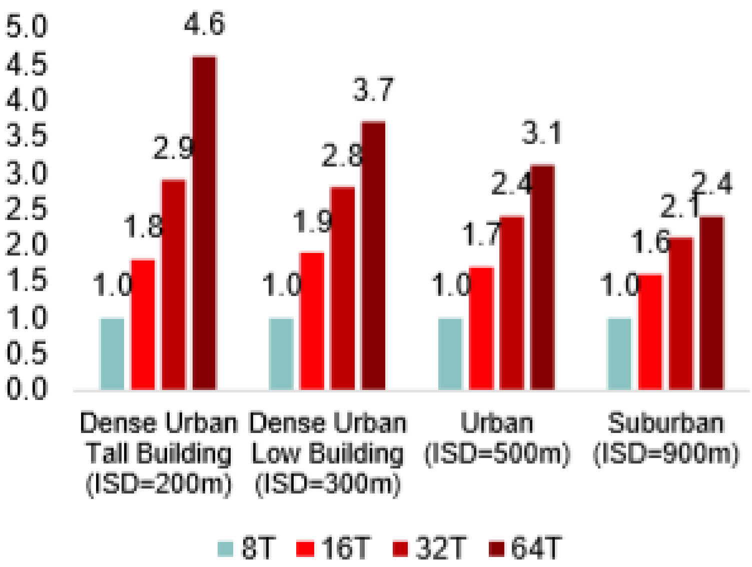
Relacionar el tráfico DL en un área y estimar la cantidad de gNB necesarios

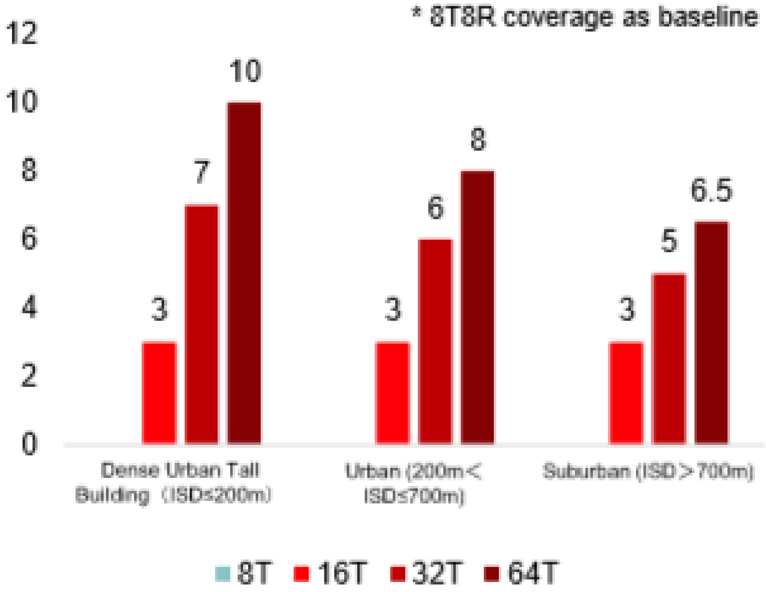
REQUERIMIENTOS Y ESTRATEGIAS

Massive MIMO

La implementación de Massive MIMO requiere tres consideraciones: rendimiento, los requisitos de instalación y ahorro de TCO.

Ganancia en términos de cobertura (dB)





- Ganancia cobertura /dB
- Co-site 4G 5G al inicio, cobert continua
- Costos de optimización, atención cobertura
- Limitaciones de peso en unidades aéreas
- Costo de gruas
- Beam 2D Vs 3D 16T 64T/64R

Fuente: GSMA

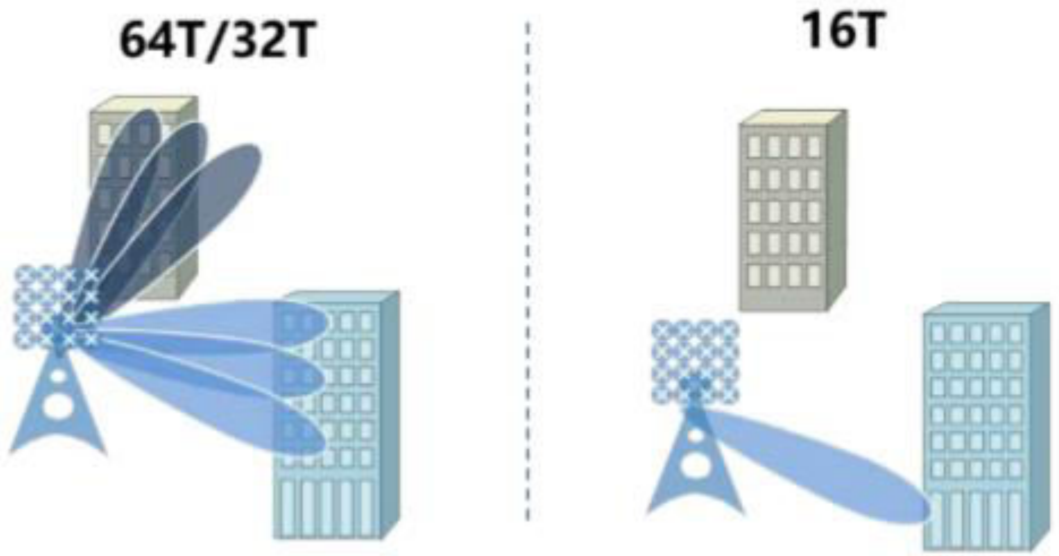
ISD Intersite distance

REQUERIMIENTOS Y ESTRATEGIAS

Massive MIMO

La implementación de Massive MIMO requiere tres consideraciones: rendimiento, los requisitos de instalación y ahorro de TCO.

- 64T / 32 T Vs 16 T
- Capex Vs Opex
- Costos de locaciones



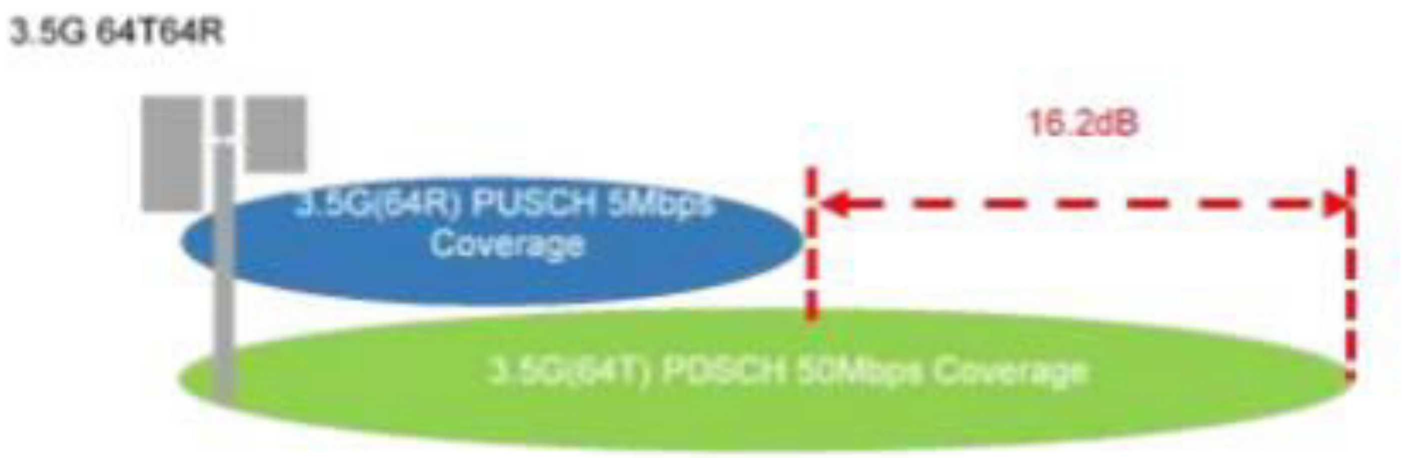
To Cover Same Area	64T	32T	16T
Require Site Number	1	1.18X	1.48X
CAPEX	1	0.95X	1.11X
OPEX	1	1.55X	2.83X

REQUERIMIENTOS Y ESTRATEGIAS

Mejoras en la cobertura

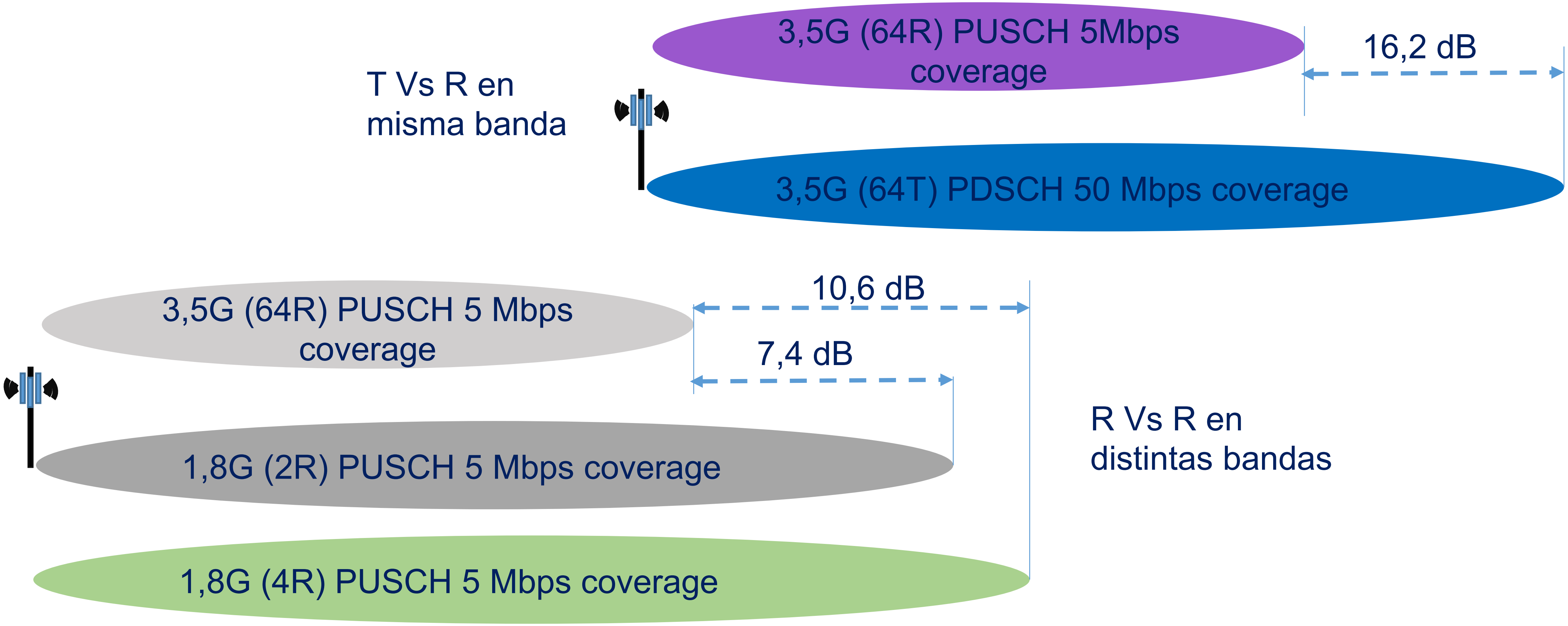
La implementación de Massive MIMO requiere tres consideraciones: rendimiento, los requisitos de instalación y ahorro de TCO.

La banda C es una de las bandas mas usadas para eMBB.
La cobertura DL es mucho mejor que la cobertura UL debido a la gran potencia de transmisión del gNodoB y a la desproporción en las asignaciones de intervalos de tiempo del enlace ascendente y descendente de NR.
La aplicación de tecnologías como la de beam forming y la señal de referencia específica de celda (CRS) -free reduce la interferencia del enlace descendente y aumenta aún más la diferencia.
Y que hay del UL?



REQUERIMIENTOS Y ESTRATEGIAS

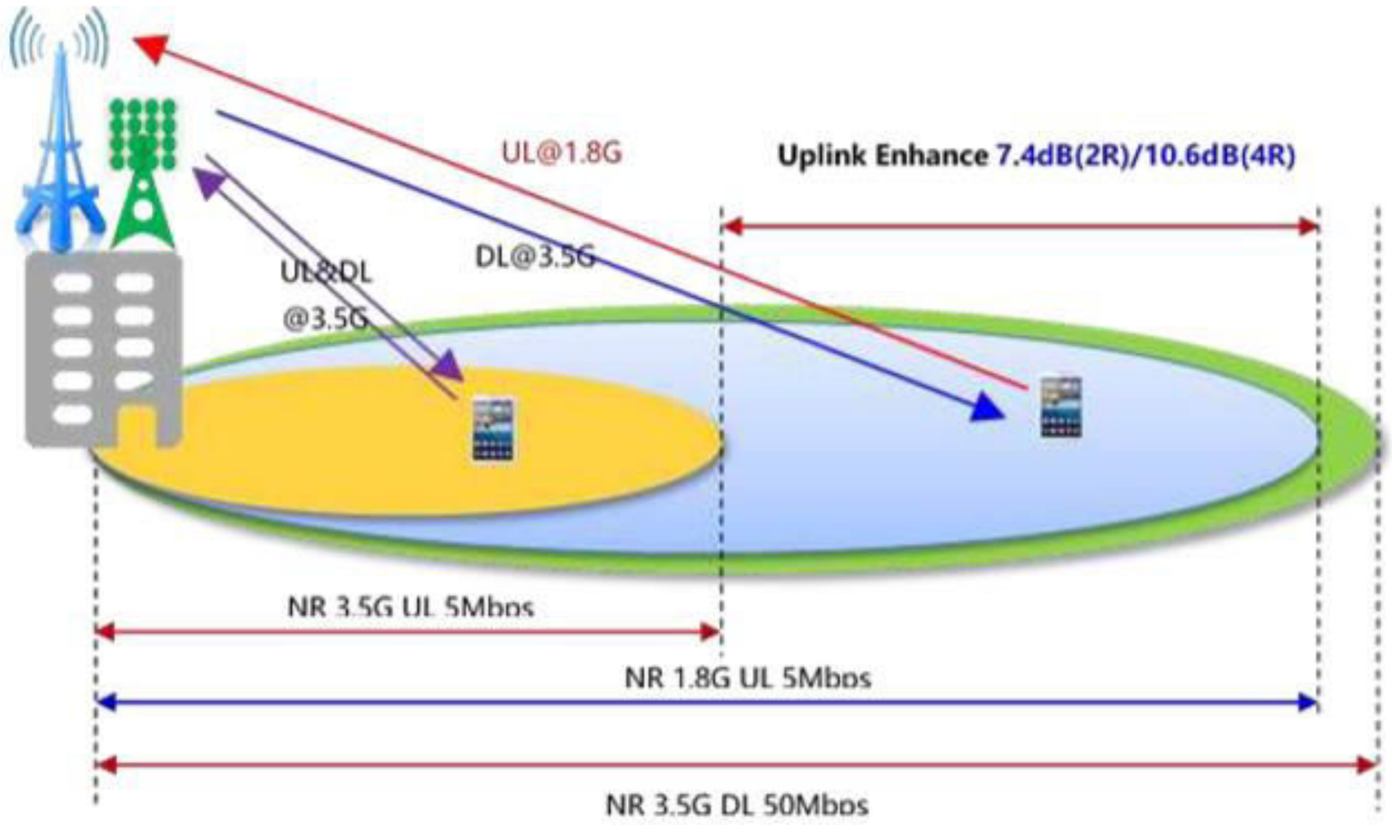
Mejoras en la cobertura

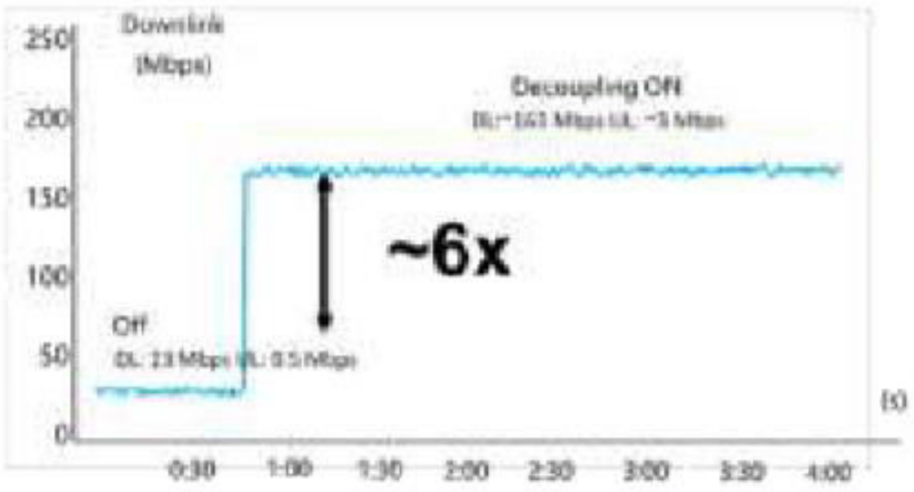


Analizar que implicancias tienen estas figuras en las elecciones de bandas.
Discutir el uso de bandas basadas en SUB 6

REQUERIMIENTOS Y ESTRATEGIAS

Mejoras en la cobertura



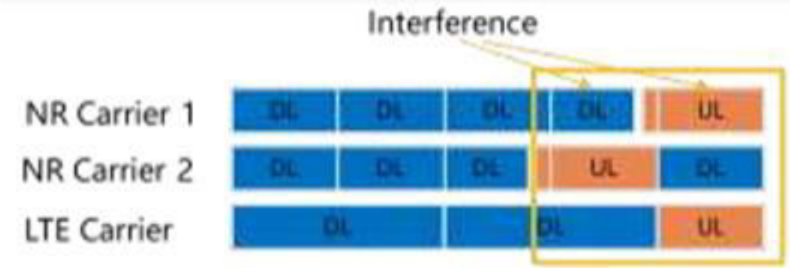


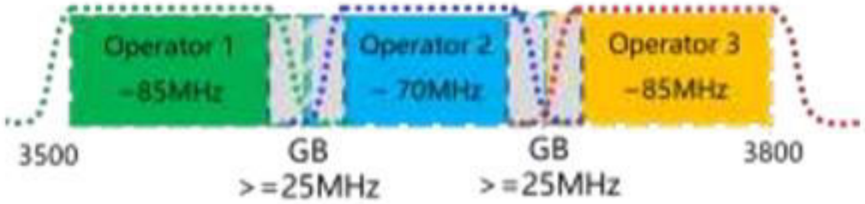
Analizar que implicancias tienen estas figuras en las elecciones de bandas. Discutir el uso de bandas basadas en SUB 6

REQUERIMIENTOS Y ESTRATEGIAS

Sincronismo en TDD

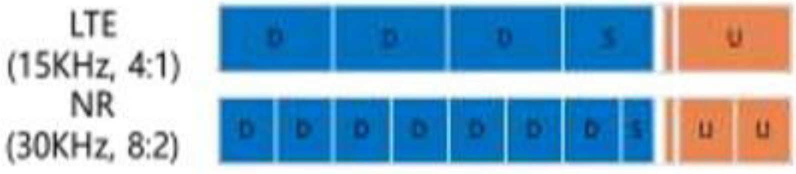
Time-slots no alineados





- Mas de 25 MHz de guarda
- Filtros para Transceiver
- Baja eficiencia

Time-slots alineados



- Sin necesidad de guarda
- Sin Filtros especiales
- Ahorro de Capex
- Alta eficiencia
- Pero……Sincronización

Analizar por qué en TDD el sincronismo es mas crítico que en FDD

REQUERIMIENTOS Y ESTRATEGIAS

Sobre la estrategia NSA y SA

	Option 3x	Option 2
Standard	17Q4	18Q2
	Option3x support 5G initial fast deployment, Option 2 0.5~1year late	
Data Experience	Option3x DC Better Handover Experience, better Peak Rate, 1year earlier than SA DC	
Coverage	DC / SUL	SUL
	NSA/SA DC ensure coverage with service continuity, SUL extends NSA/SA NR coverage.	
Voice	VoLTE	VoNR
	Suitable solution with the experience at same level	
Service Readiness	eMBB	eMBB/uRLLC/mMTC
Deployment complexity	DC	SUL
	NSA with mandatory DC needs LTE upgrade; SUL which extends SA Coverage need LTE upgrade, complexity at same level	
Relevance with existing LTE	DC	SUL / Refarming
	DC, SUL are both relevant to LTE; Coordination after Refarming Legacy LTE is important, NSA/SA are both closely relevant to legacy LTE.	

Analizar y desafiar los plazos que considera GSMA

REQUERIMIENTOS Y ESTRATEGIAS

Transporte y backahul

Midhaul

- Cambio de arquitectura
- Desagregación
- Anillos de agregacion entre DU y CU

Fronthaul

- Crecimiento de datos
- Latencia
- Escalabilidad
- Densificación de RAN
- Micro celdas
- Cloud RAN.

eCPRI

- Conexión entre RRU y CU/DU para 5G.
- Granularidad de 25 Gbit/s.
- Tambien para 4G
- Jitter/latencia.

Dispositivos

Borde

IPSec en el transporte
Edge Computing
- VNF /CNF en el borde

Terminación de túneles IPSec en los POP de borde

Sincronismo

- 5G, mayormente TDD
- Sincronización de fase mandatoria
- GPS como primer paso, costoso, inseguro
- PTP ITU profiles

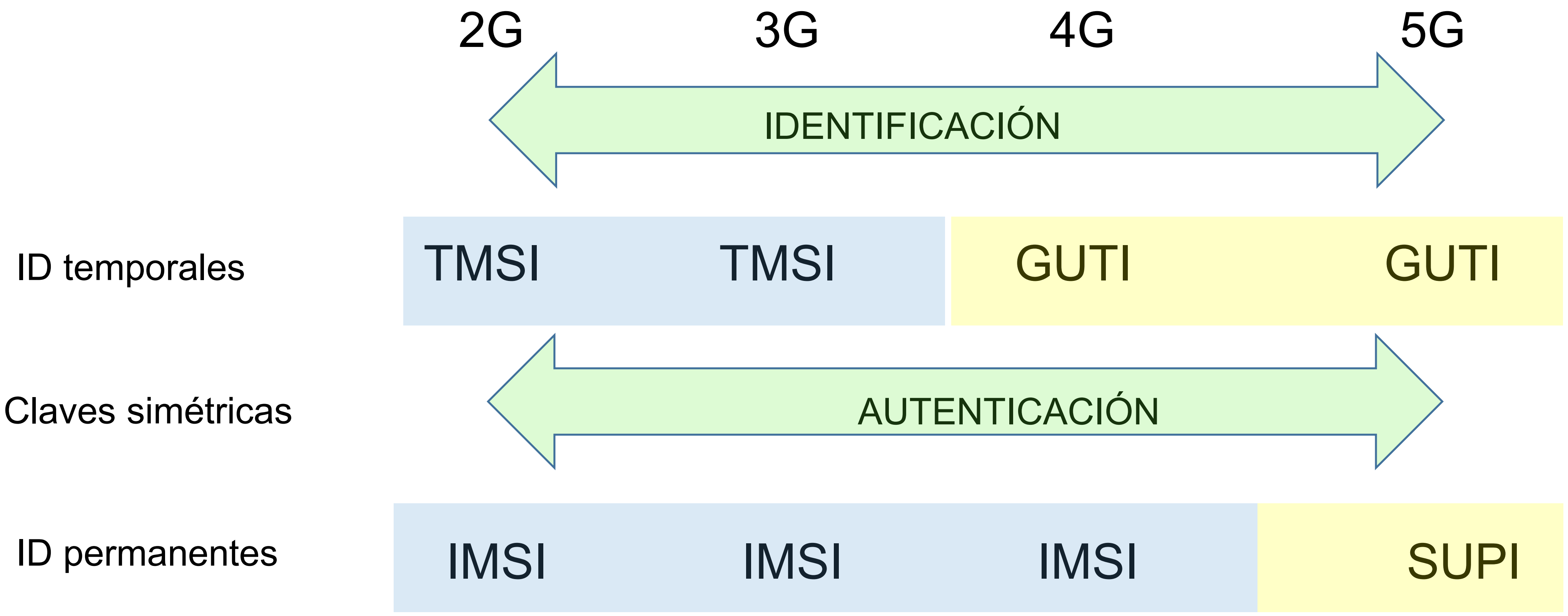
REQUERIMIENTOS Y ESTRATEGIAS

Algunas pruebas tipicas NSA

Content	Item	Function
LTE/NR DC	LTE/NR Interface	To test X2 interface
	MCG Bearer	To test MCG bearer functionality
	SCG Bearer	To test SCG bearer functionality
	MCG Split Bearer	To test MCG split bearer functionality
	SCG Split Bearer	To test SCG split bearer functionality
LTE/NR DC mobility management	SN Addition	To test SgNB addition functionality
	SN Re-configuration	To test SgNB re-configuration functionality
	LTE/NR DC Handover	To test LTE/NR DC handover functionality
Data split algorithm	DL Data Split Algorithm	To test DL data split algorithm
	UL Data Split Algorithm	To test UL data split algorithm
Performance	Single UE DL Throughput	To test single UE DL throughput
	Single UE UL Throughput	To test single UE UL throughput
	Cell DL Peak Throughput	To test cell DL throughput
	Cell UL Peak Throughput	To test cell UL throughput
Latency	Control Plane Latency	To test control plane latency
	User Plane Latency	To test user plane latency
Massive MIMO	SU-MIMO DL	To test SU-MIMO DL functionality (2 steams)
	MU-MIMO DL	To test MU-MIMO DL functionality (16/24 steams)
	MU-MIMO UL	To test MU-MIMO UL functionality (8/16 steams)

5G IDENTIDADES DE SUSCRIPCIÓN y RED DE ACCESO SA

5G IDENTIDADES DE SUSCRIPCIÓN



5G security specifications do not allow plain-text transmissions of the SUPI over the radio interface. Instead, an Elliptic Curve Integrated Encryption Scheme (ECIES) – based privacy-preserving identifier containing the concealed SUPI is transmitted. This concealed SUPI is known as SUCI (Subscription Concealed Identifier)

IMSI: International Mobile Subscriber Identity
SUPI: Subscription Permanent Identifier
TMSI: Temporary Mobile Subscriber Identity

5G IDENTIDADES DE SUSCRIPCIÓN

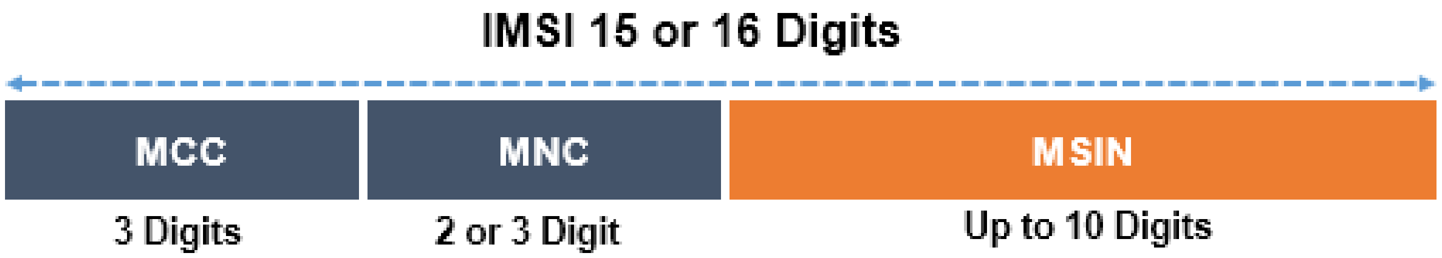
Subscription Permanent Identifier (SUPI)

A SUPI is a 5G globally unique Subscription Permanent Identifier (SUPI) allocated to each subscriber and defined in 3GPP specification TS 23.501. The SUPI value is provisioned in USIM and UDM/UDR function in 5G Core.

A Valid SUPI can be either of following

- An IMSI (International Mobile Subscriber Identifier) as defined in TS 23.503 for 3GPP RAT
- NAI (Network Access Identifier) as defined in RFC 4282 based user identification as defined in TS 23.003 for non-3GPP RAT

A SUPI is usually a string of 15 decimal digits. The first three digits represent the Mobile Country Code (MCC) while the next two or three form the Mobile Network Code (MNC) identifying the network operator. The remaining (nine or ten) digits are known as Mobile Subscriber Identification Number (MSIN) and represent the individual user of that particular operator. SUPI is equivalent to IMSI which uniquely identifies the ME, is also a string of 15 digits.



IMSI: International Mobile Subscriber Identity
SUPI: Subscription Permanent Identifier
TMSI: Temporary Mobile Subscriber Identity

5G IDENTIDADES DE SUSCRIPCIÓN

Subscription Concealed Identifier (SUCI)

Subscription Concealed Identier (SUCI) is a privacy preserving identifier containing the concealed SUPI. The UE generates a SUCI using a ECIES-based protection scheme with the public key of the Home Network that was securely provisioned to the USIM during the USIM registration.

Only the MSIN part of the SUPI gets concealed by the protection scheme while the home network identifier i.e. MCC/MNC gets transmitted in plain-text. The data fields constituting the SUCI are following

IMSI: International Mobile Subscriber Identity
SUPI: Subscription Permanent Identifier
SUCI: Subscription Concealed Identier
TMSI: Temporary Mobile Subscriber Identity

5G IDENTIDADES DE SUSCRIPCIÓN

•**SUPI Type:** consisting in a value in the range 0 to 7. It identifies the type of the SUPI concealed in the SUCI. The following values are defined

- 0: IMSI
- 1: Network Access Identifier (NAI)
- 2 to 7: spare values for future use.

•**Home Network Identifier:** identifying the home network of the subscriber. When the SUPI Type is an IMSI, the Home Network Identifier is composed of MCC and MNC. When the SUPI type is a Network Access Identifier, the Home Network Identifier consists of a string of characters with a variable length representing a domain name. e.g. user@techno.com

•**Routing Indicator:** It is consist of 1 to 4 decimal digits assigned by the home network operator and provisioned within the USIM.

•**Protection Scheme Identifier:** It is consist of a value in the range of 0 to 15 and represented with 4 bits

- null-scheme 0x0
- Profile <A> 0x1
- Profile <B> 0x2

•**Home Network Public Key Identifier:** It is consist of a value in the range 0 to 255. It represents a public key provisioned by the HPLMN and it is used to identify the key used for SUPI protection. In case of null-scheme being used, this data field shall be set to the value as 0

•**Protection Scheme Output :** It is consist of a string of characters with a variable length or hexadecimal digits, dependent on the used protection scheme

5G IDENTIDADES DE SUSCRIPCIÓN

SUPI, Subscription Permanent Identifier: identifies a subscription in the 5GS, used only within the 3GPP system. Possible formats:

1. IMSI, MCC + MNC + MSIN
2. Network Access Identifier (RFC 7542)
   - IMSI based, IMSI@nai.5gc.mnc<MNC>.mcc<MCC>.3gppnetwork.org
   - Non-IMSI based, username@realm

SUPI allocated to the 3GPP UE shall always be based on an IMSI for interworking with the EPC.

SUCI, Subscription Concealed Identifier: "Privacy preserving identifier containing the concealed SUPI". Subscription-specific part of the SUPI is encrypted, the home network information remains in cleartext for routing. UE encrypts the SUPI using a hnw-specific public key, SUCI is decrypted in the UDM using a hnw-specific private key.

5G-GUTI, 5G Globally Unique Temporary Identifier: a temporary subscription identifier allocated by the AMF. Purpose:

- Subscription identity confidentiality
- Identification of the last used AMF

<5G-GUTI> = <GUAMI><5G-TMSI>, where:

<GUAMI> = <MCC><MNC><AMF Identifier> and <AMF Identifier> = <AMF Region ID><AMF Set ID><AMF Pointer>

Common value for 3GPP and non-3GPP accesses.

GPSI, Generic Public Subscription Identifier: identifies the 3GPP subscription towards the data networks outside the 3GPP system, can also be used inside the 3GPP networks. Possible formats:

1. MSISDN
2. External Identifier, <Local Identifier>@<Domain Identifier>

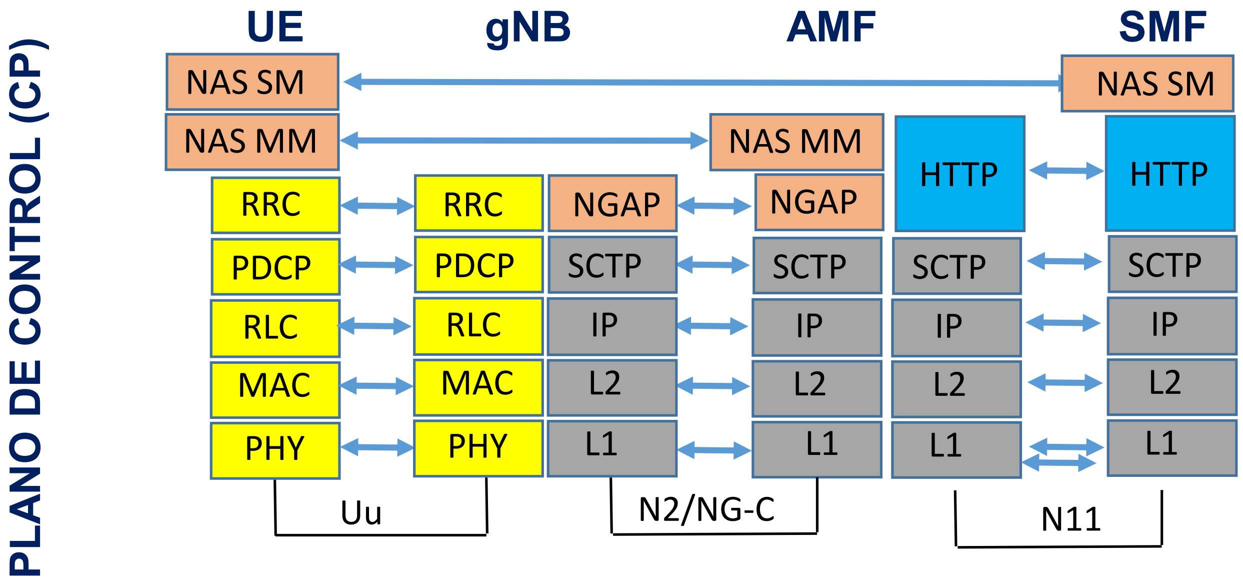
GPSI ←→ SUPI binding created in the NEF. There is no implied 1:1 relationship between the SUPI and the GPSI.

PEI, Permanent Equipment Identifier: identifies the UE, the only format in R15 is IMEI.

MNC: Mobile Network Code
MSIN Mobile Subscription Id Number
NEF: Network Exposure Function
TMSI: Temporary Mobile Sub Identity
UDM: Unified Data Management

3GPP 3RD Gen Partnership Project
AMF: Access and Mobility Function
GUAMI: Globally Unique AMF Identifier
IMEI: Internat Mobile Station Eq Identity
MCC: Mobile Country Code

STACK DE PROTOCOLOS CON NG-RAN



Nuevo!!!

Nombre nuevo, reemplaza protocolo similar

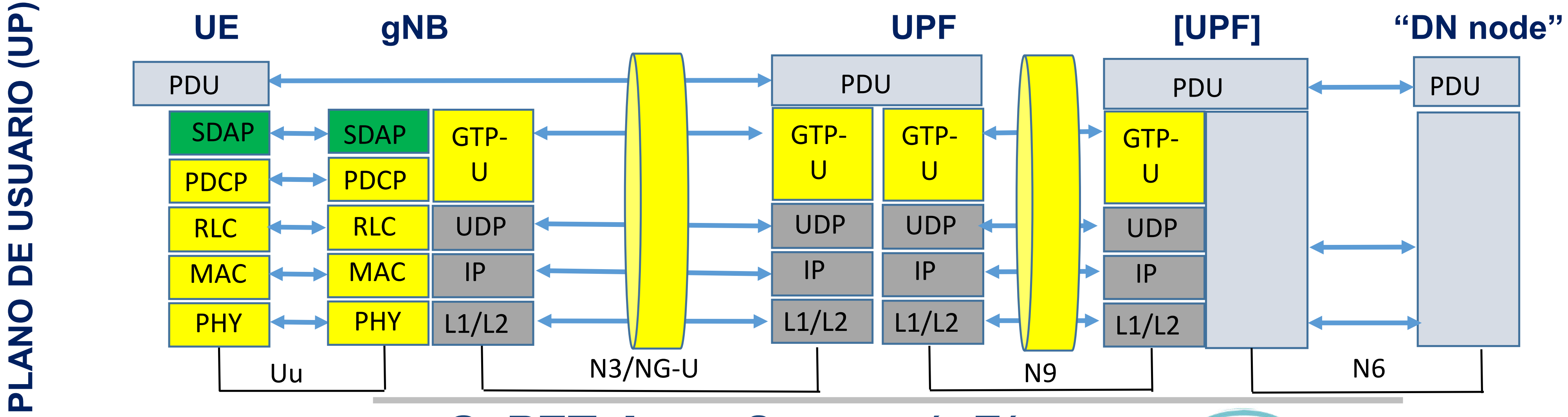
No cambia el nombre, mejorado

El mismo que en LTE

Protocolo viejo, pero nuevo para 3GPP

NGAP: NG Application Protocol
Ref,: TS 38.413. NG-RAN; .

SDAP: Service Data Adaptation Protocol
Ref.: TS 37.324. EUTRA and NR



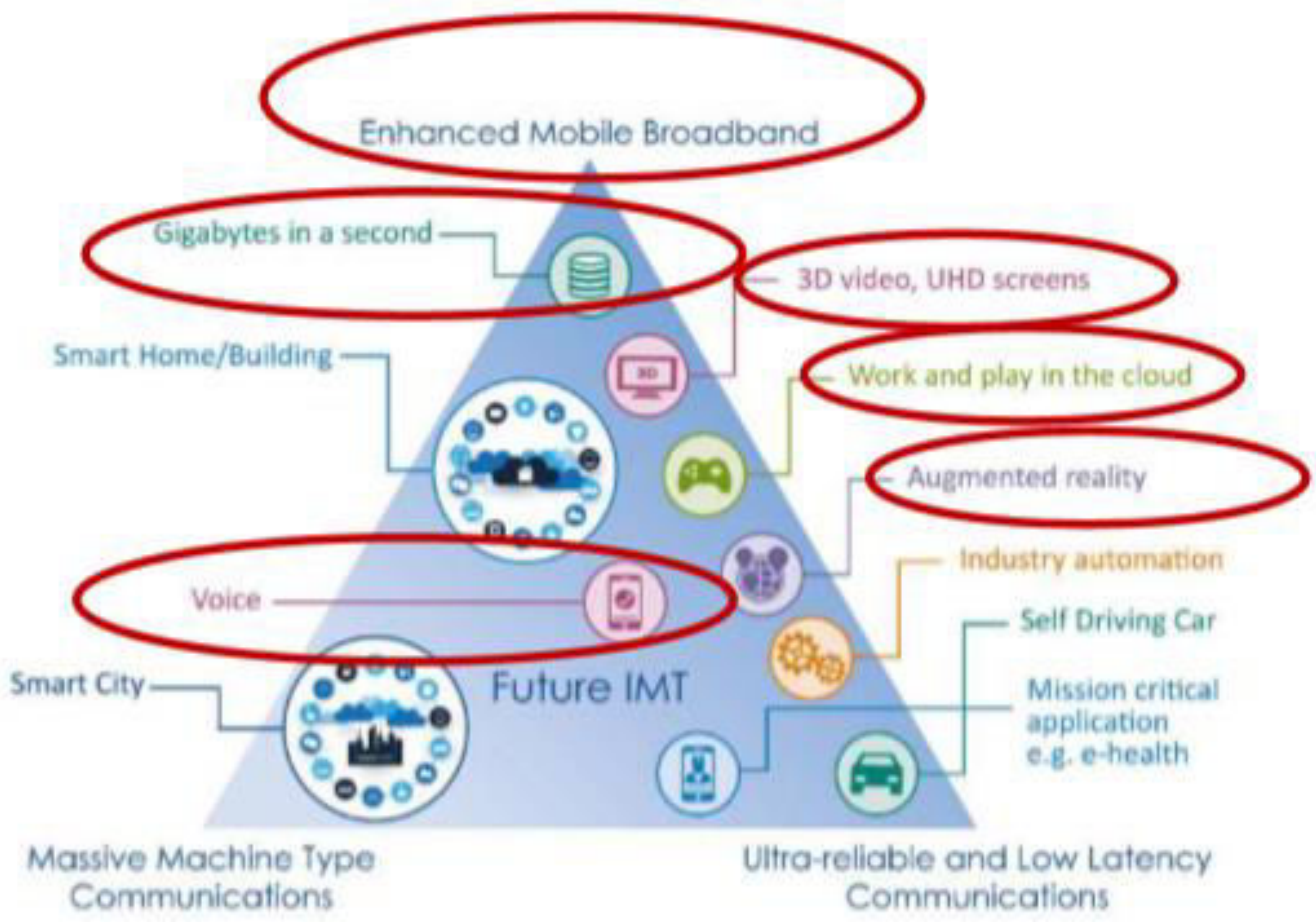
NETWORK SLICING

SST = 1, eMBB (enhanced Mobile Broadband)
Slice suitable for the handling of 5G enhanced Mobile broadband, useful, but not limited to the general consumer space mobile broadband applications including streaming of High Quality Video, Fast large file transfers etc. It is expected this SST to aim at supporting high data rates and high traffic densities as outlined in Table 7.1-1 "Performance requirements for high data rate and traffic density scenarios" in TS 22.261

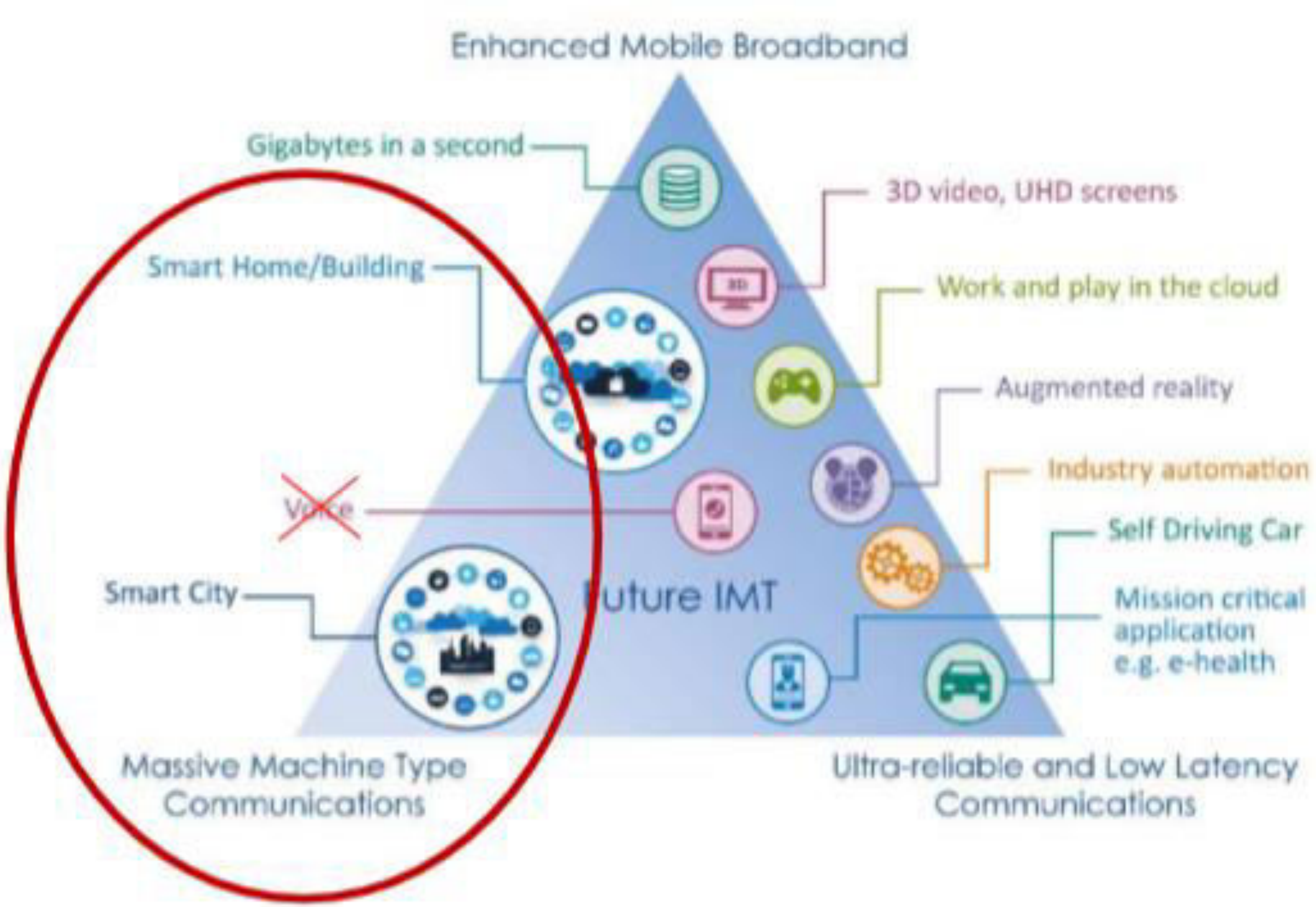
SST = 2, URLLC (Ultra-Reliable Low Latency Communication)
Supporting ultra-reliable low latency communications for applications including, industrial automation, (remote) control systems. This SST is expected to aim at supporting the requirements in Table 7.2.2-1 "Performance requirements for low-latency and high-reliability services." in TS 22.261 related to high reliability and low latency scenarios

SST = 3, MIoT (Massive IoT), mMTC (massive Machine Type Communication)
Allowing the support of a large number and high density of IoT devices efficiently and cost effectively.

NETWORK SLICING - eMBB

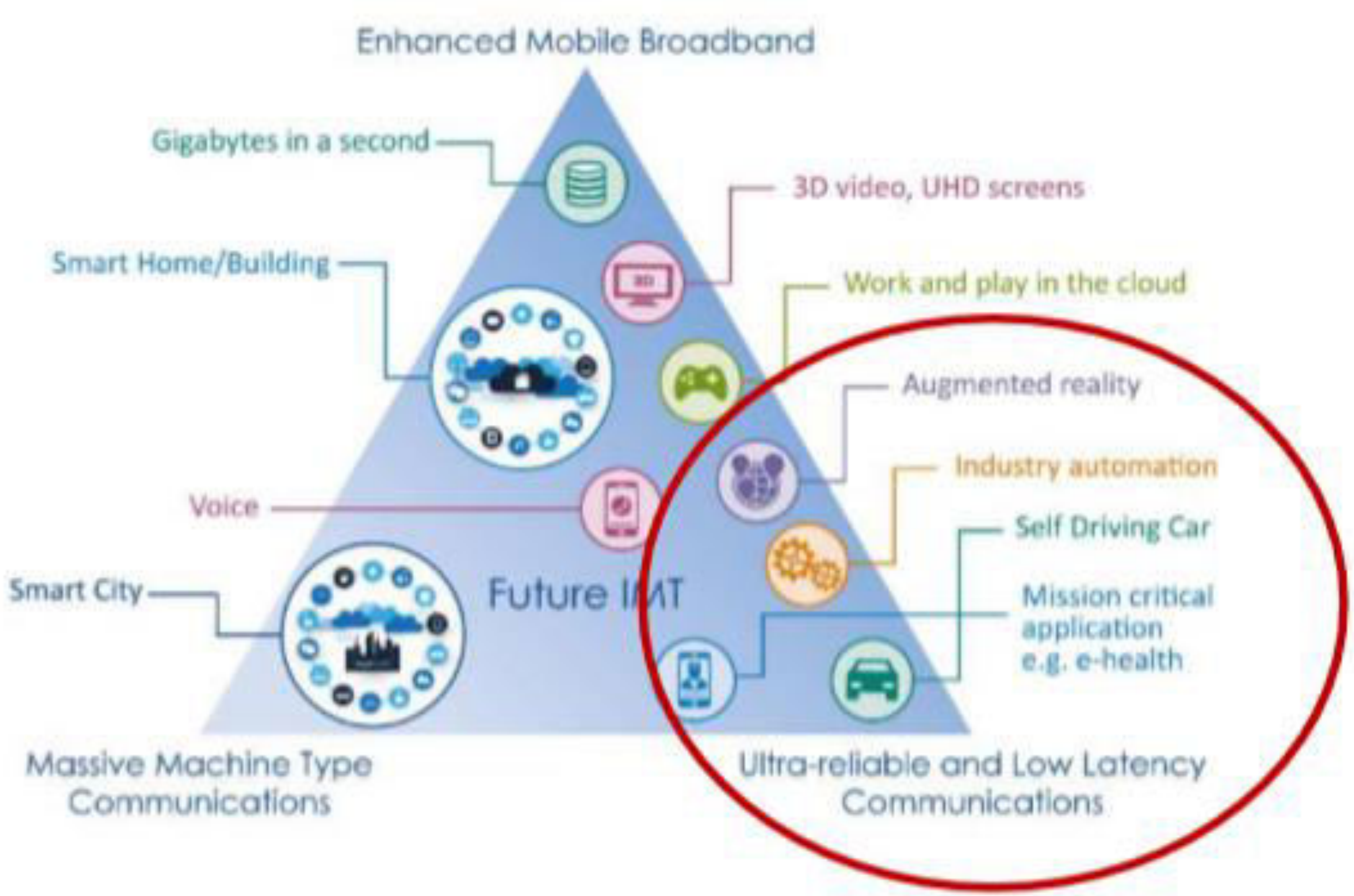


NETWORK SLICING - mMTC



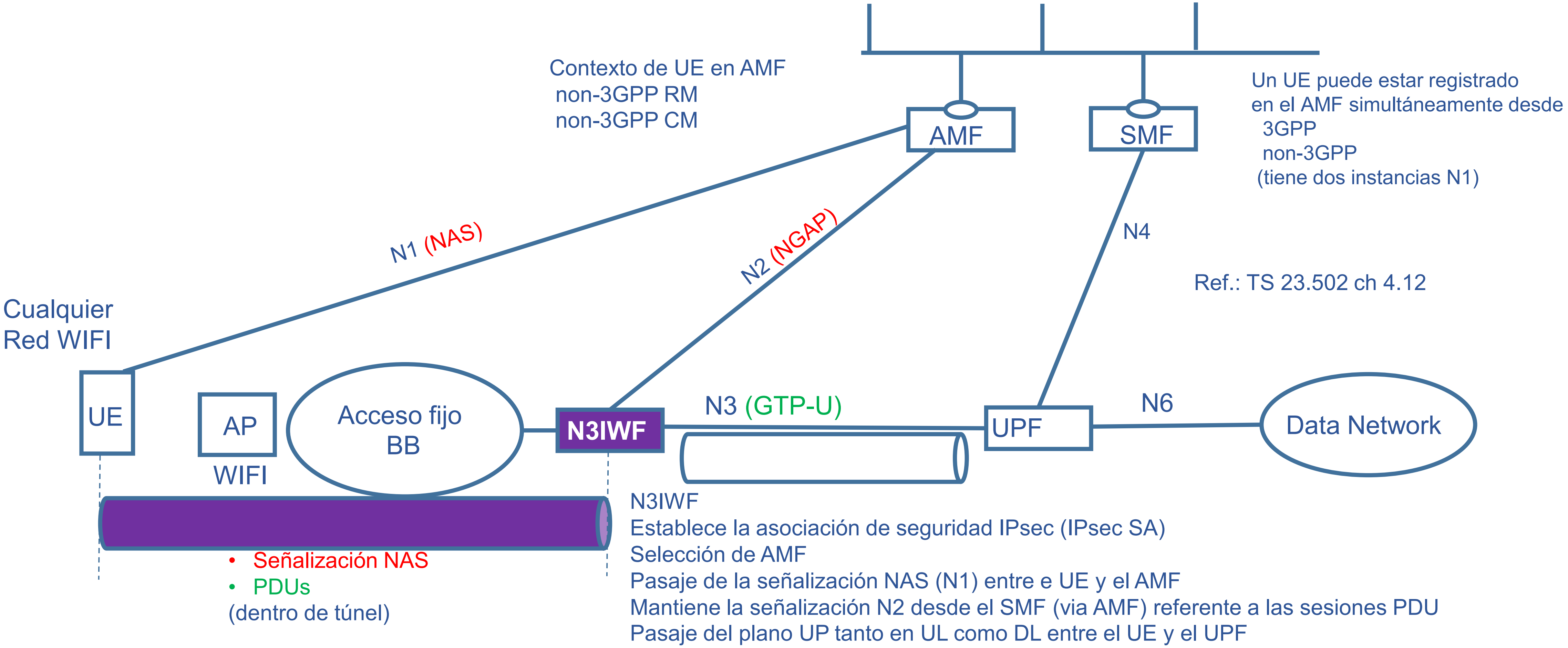
Observar el UP para servicios de Internet y para IMS. Cual es la diferencia?

NETWORK SLICING – Ultra-Reliable and Low Latency Communication



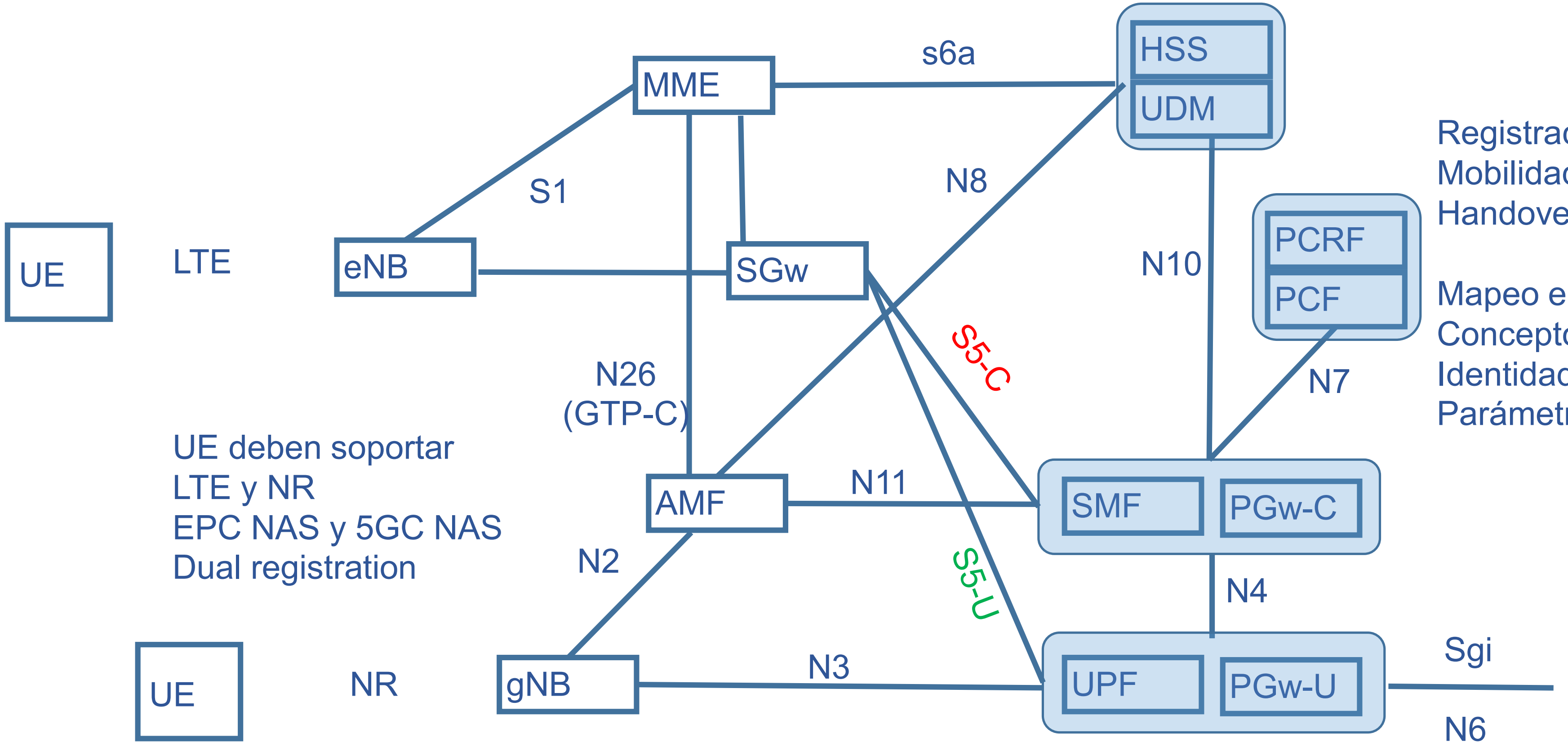
Cual es la latencia máxima admisible? Y qué ocurre en el borde de la red?

ACCES NON -3GPP A CORE 5G



Analizar NAS y NGAP.. Que diferencia hay entre ellos?

5G REPRESENTACIÓN DE PUNTOS DE REFERENCIA, HOME ROUTING



Registración
Mobilidad / TA Updates
Handovers

Mapeo entre 4G y 5G
Conceptos (Bearers VS QoS Flows etc)
Identidades (4G-GUTI Vs 5G GUTI etc)
Parámetros de QoS

Ref.:
TS 23.501
TS 23.502

Discutir mapeos entidades duales

NEW RADIO-EVOLUCIÓN DE LTE

2009	2011	2016	2017	2018	2019	2020	2021
Rel-8	Rel-10	Rel-13	Rel-14	Rel-15	Rel-16	Rel-17	

Mobile Broadband
VoLTE

Need for more!
New use cases
Internet of Things (MTC)
Device to Device (ProSe)
Technical Evolution
WiFi everywhere

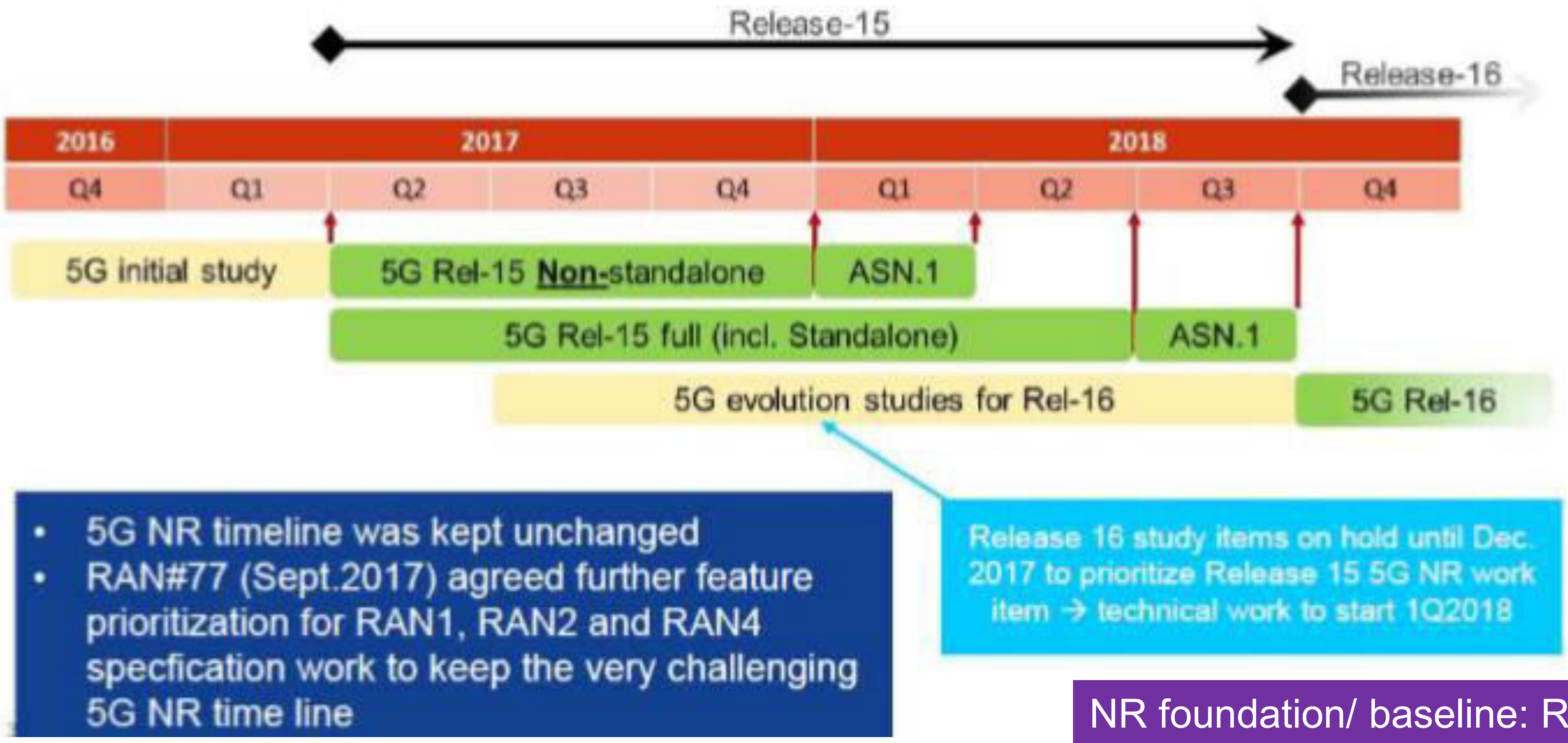
LTE → LTE Advanced → LTE Advanced Pro → LTE Advanced Pro Cont.

New Radio NR.

1,4-20 MHz Carriers
FqNeed for more!
New use cases
Internet of Things (MTC)
Device to Device (ProSe)
Technical Evolution
WiFi everywhere

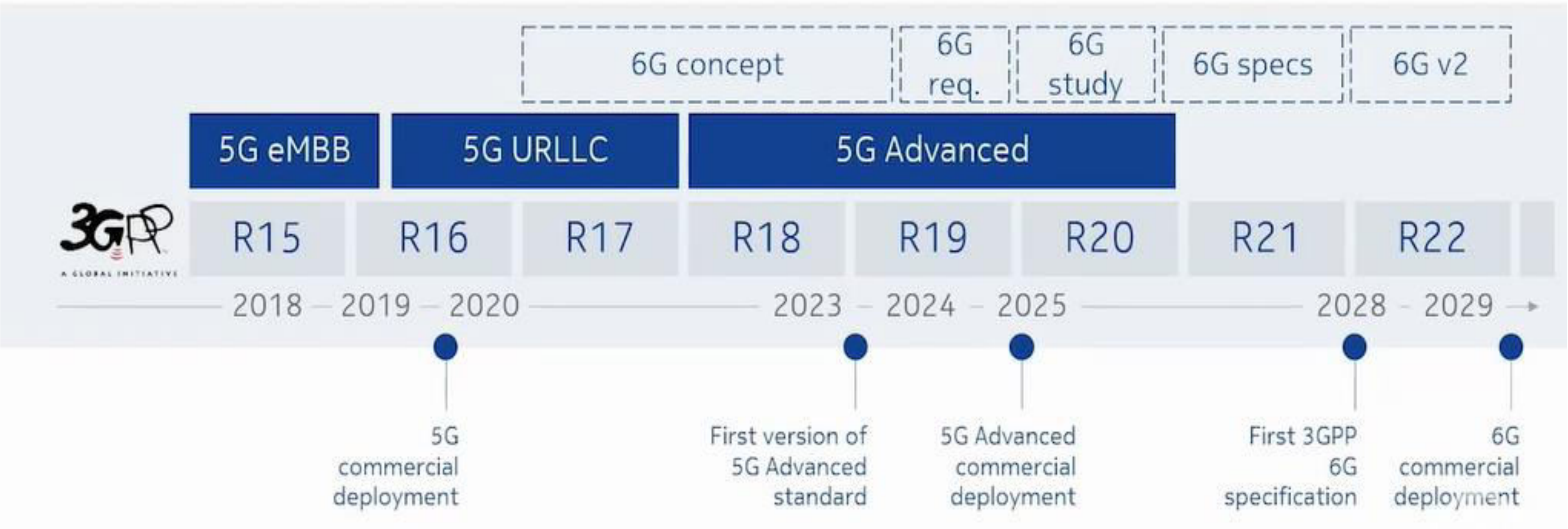
- Carrier Aggregation
- Dual Connectivity
- Coordinated Multipoint
- HetNets /Small Cells
- Advanced MIMO and modulation
- New UE categories
- NB-IoT (narrow carriers- 180 KHz)
- LTE-M
- Licensed Assisted Access (LWA)
- LTE WAN Aggregation
- Enhancements improvements

3GPP NR TIME LINE

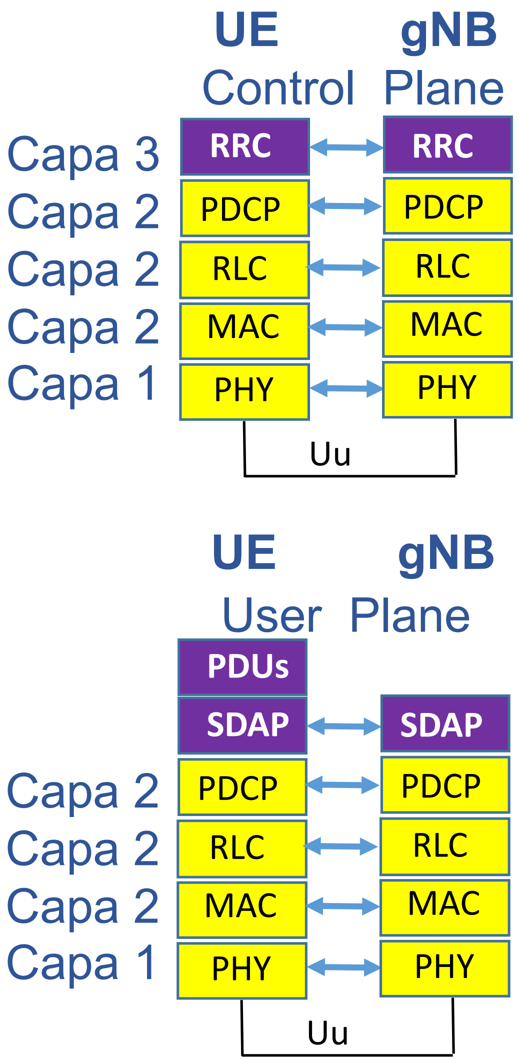


NR foundation/ baseline: R15
NR New features: R16 and next

3GPP NR TIME LINE



STACK DE PROTOCOLOS DE NR



Capa 3

RRC: Radio resource Control (TS 38.331).

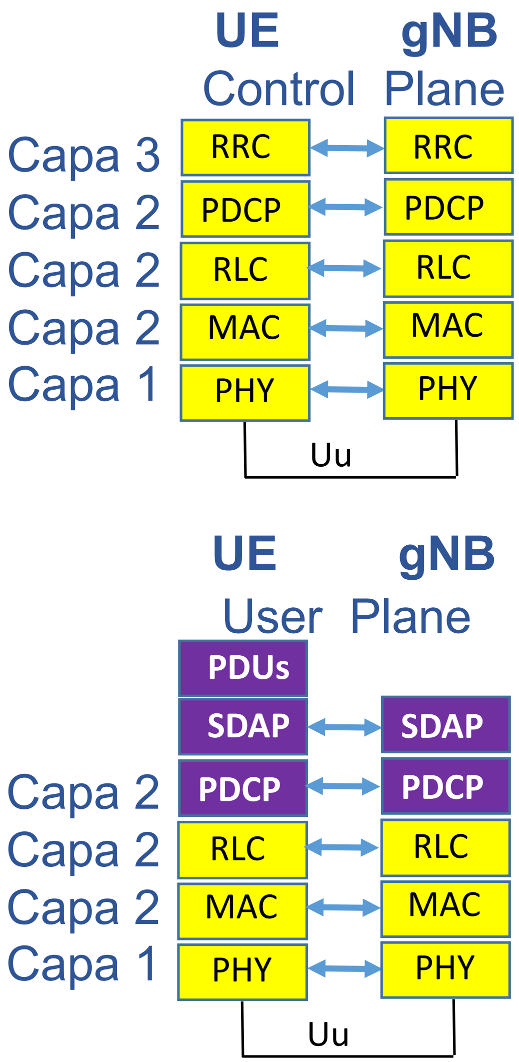
- Broadcast de los SBI (System Information) relacionados a AS y NAS.
- Paging iniciado tanto por 5GC como por NR-RAN.
- Establecimiento, mantenimiento, liberación de RRC connection entre el UE y NG-RAN, incluyendo los siguientes:

    -Adición, modificación y liberación de Carrier Aggregation.
    -Adición, modificación y liberación de Dual connectvity en NR, o entre E-UTRA y NR.
- Funciones de Seguridad incluyendo gerenciamiento de claves.
- Establecimiento, configuración, mantenimiento y liberación de SRBs y DRBs.
- Funciones de movilidad, tales como:

    -Handover y transferencia de contexto.
    -Selección y reselección de celdas y control de Selección y reselección de celdas Mobilidad Inter-RAT.

- Funciones de manejo de QoS.
- Reporte de mediciones del UE y control de los reportes.
- Detección de y recuperación de fallas de enlace de radio.
- Transferencia de mensajes NAS desde/hacia CORE / UE.

STACK DE PROTOCOLOS DE NR



CAPA 2

Flujos de QoS

SDAP (TS 37.324)

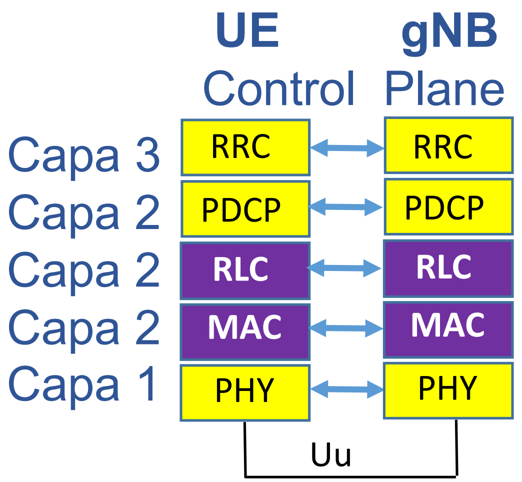
- Mapeo entre un flujo de QoS y un DRB (Data Radio Bearer)
- Marcado del QoS flow ID (QFI), para UL y para DL

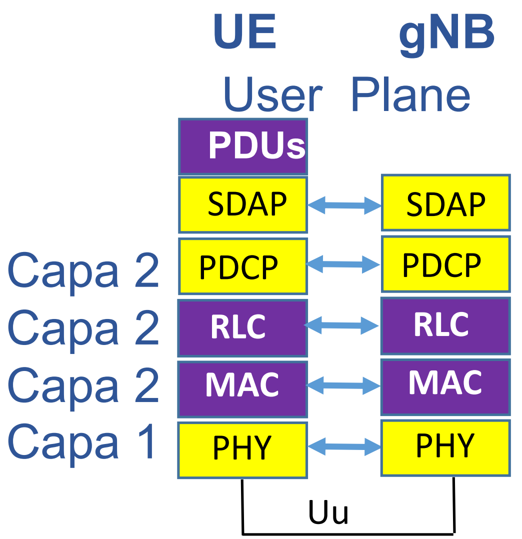
Radio Bearers (SRBs y DRBs)Canales lógicos

PDCP (TS 38.323)

- Cifrado, protección de integridad
- Numeración de secuencia
- Compresión de Header
- Ruteo de las PDU de PDCP (en caso de split de Portadoras)
- Duplicación de las PDUs de PDCP
- Reordenamiento y detección de duplicados
- Retransmisión de SDUs de PDCP

STACK DE PROTOCOLOS DE NR





CAPA 2

Canales RLC

RLC (TS 38.322)

- Segmentación (AM y UM) y reensamblado
- Numeración de secuencia (AM y UM)
- Corrección de errores sobre ARQ (solo AM)
- Detección de duplicaciones (solo AM)
- Descartado de SDU de RLC (AM y UM)
- Protocolo de detección de errores (solo AM)

Canales lógicos

MAC (TS 38.321)

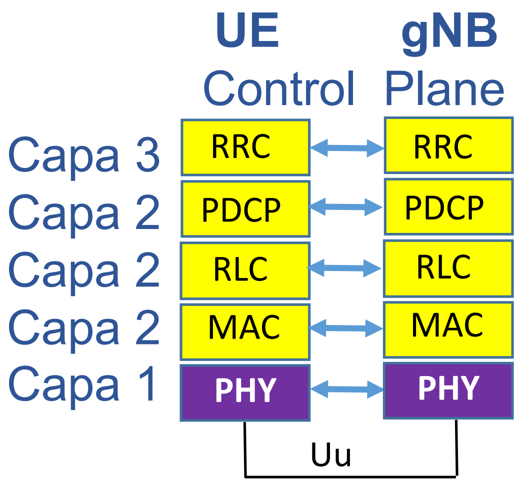
- Mapeo entre los canales lógicos y los canales de transporte
- Mux /demux de canals lógicos de/hacia canales de transporte
- Corrección de error a través de HARQ
- Manejo de prioridades entre UEs por medio de un scheduling dinámico
- Manejo de prioridades entre los canales lógico de un UE.

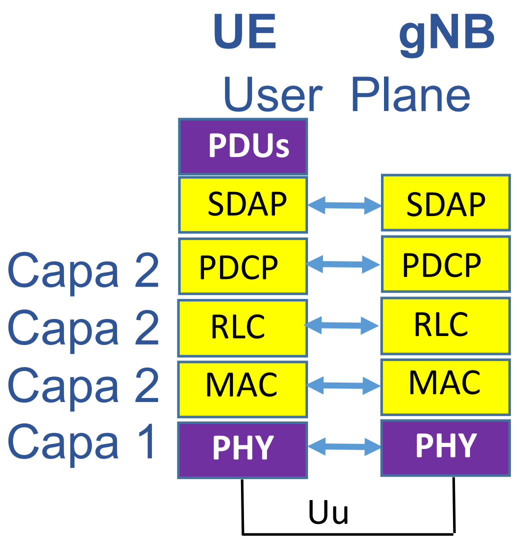
Canales de Transporte

AM:Acknowledge Mode
UM: Unacknowledged mode

SDU: Service Data Unit. This layer will modify the data and convert it into a PDU or a Protocol Data Unit.

STACK DE PROTOCOLOS DE NR





CAPA 1

Canales de Transporte

PHY (TS 38.402, 38.211, 38.411…)

- transport block CRC attachment
- Segmentación del bloque de código y bloque de código CRC
- Codificación del canal. LDPC y codificación Polar
- Procesamiento del híbrido ARQ Capa física y rate matching
- Entrelazado de bits
- Modulación BPSK, QPSK, 16 QAM, 64 QAM, 256 QAM; etc)
- Mapeo de capa y pre codificación
- Mapeo con los recursos asignados y puertos de antenas
- Radio OFDM

LDPC:Low Density Parity Check

RLEASE 15 DE 3GPP. LA BASE

BANDAS- RESUMEN

Main spectrum bands	700MHz–2.6GHz	3.5GHz, 5GHz	27.5–31GHz ('28GHz')	37–42.5GHz ('39 GHz')	70–80GHz ('E-band')
Usage	Traditional mobile bands	New bands to be released for 5G			
			mmWave		
Multiples of assignments	Tens of MHz		100s of MHz		
Amount available	<1GHz		45GHz		
Maximum cell radii	Tens of kilometers	~1km	Tens to hundreds of meters, depending on LoS		

BANDAS-RESUMEN

NR *operating band*	Uplink (UL) *operating band* BS receive / UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) *operating band* BS transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL

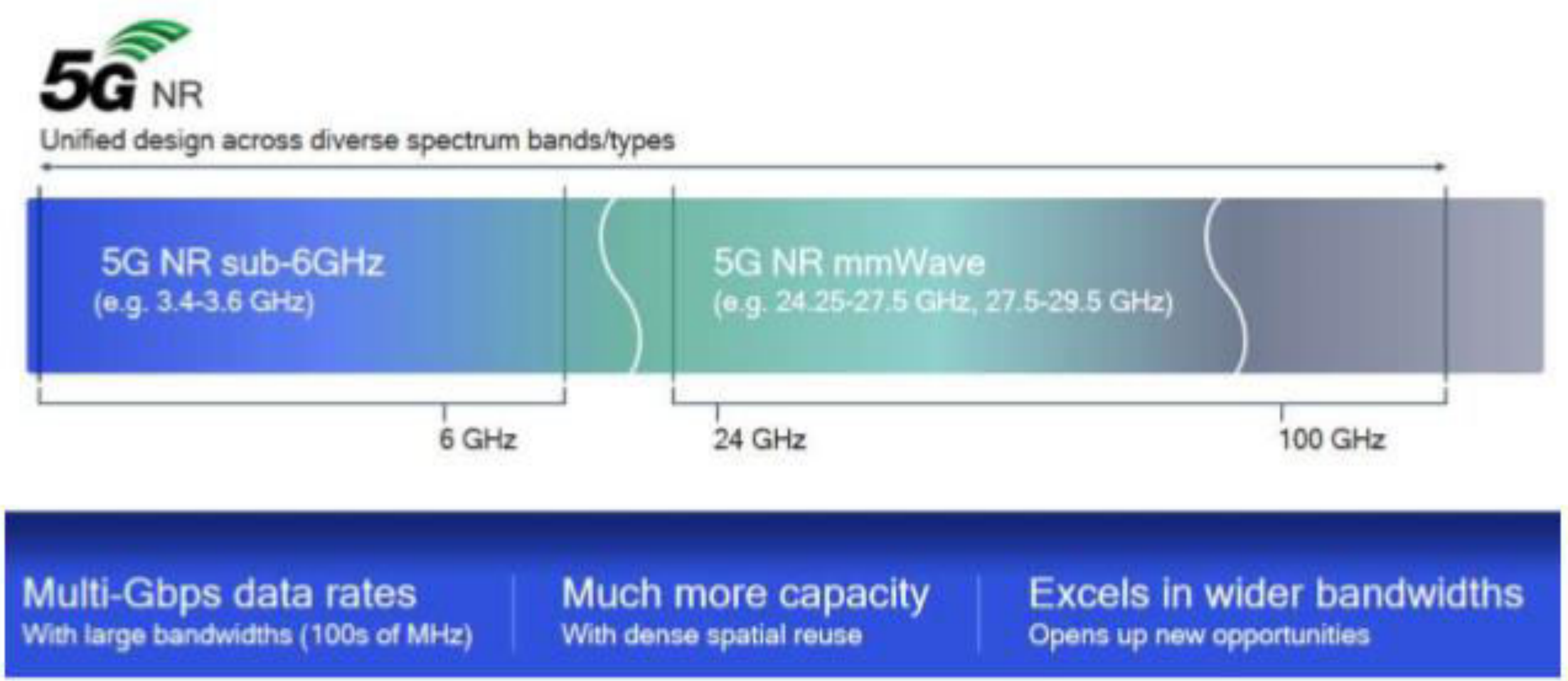
Ref.: TS 38.104

BANDAS-RESUMEN

NR *operating band*	Uplink (UL) and Downlink (DL) *operating band* BS transmit/receive UE transmit/receive F_{UL_low} – F_{UL_high} F_{DL_low} – F_{DL_high}	Duplex Mode
n257	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	TDD
n260	37000 MHz – 40000 MHz	TDD

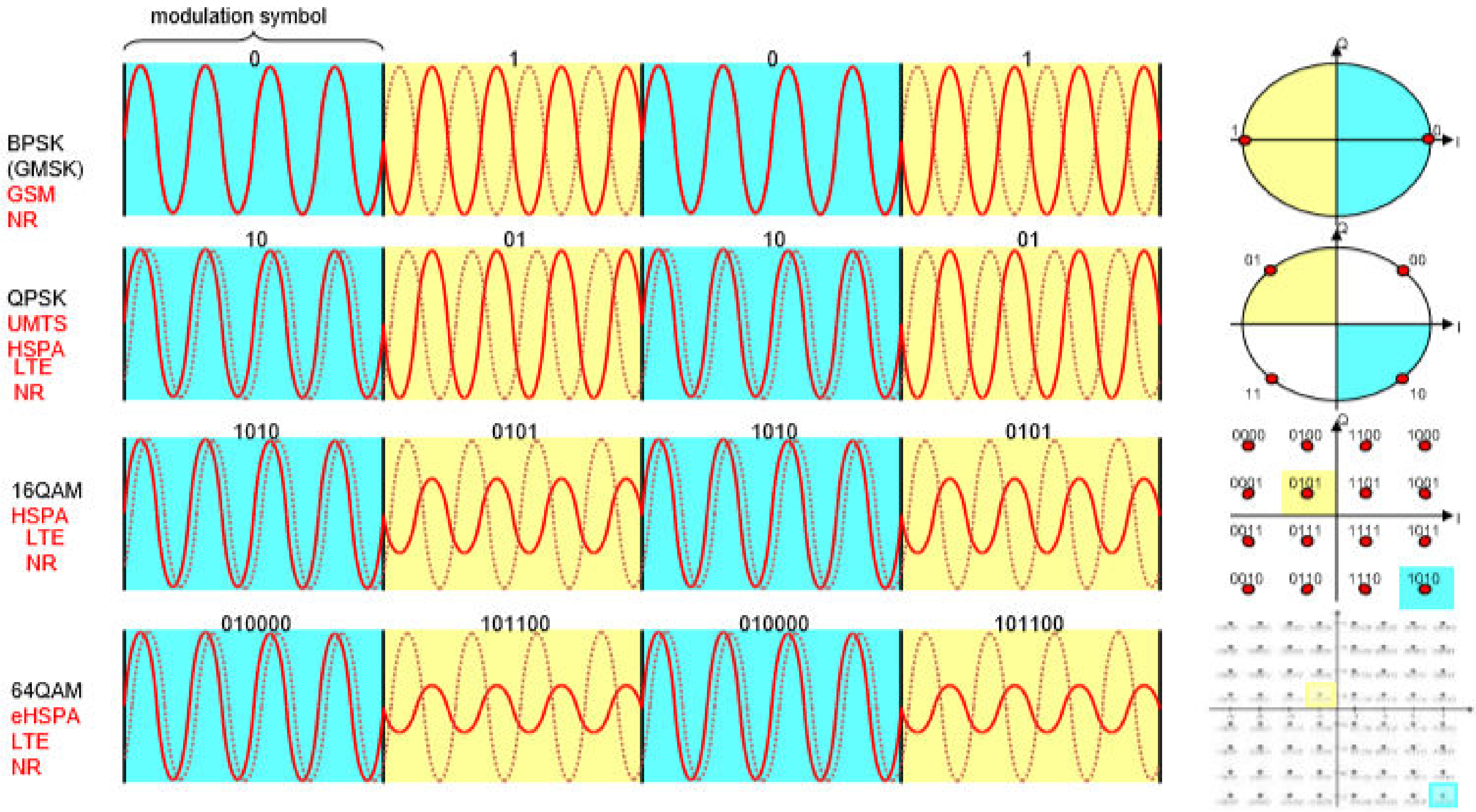
Ref.: TS 38.104

ONDAS MILIMÉTRICAS



Discutir el rol de bandas no licenciadas en FH

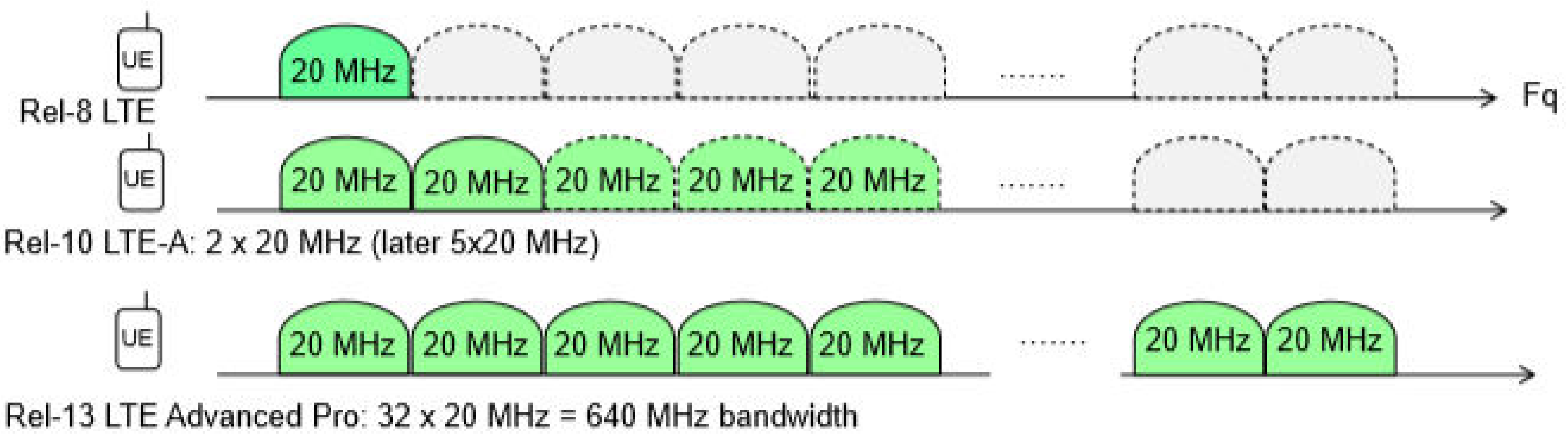
MODULACIÓN



Proponer un ejemplo

CARRIER AGREGATION EN LTE

Carrier aggregation fue introducida en release8 para HSPA (3G), pero se hizo realidad en LTE.
Consiste en la agregación de multiples portadoras (carriers) para ofrecer mayors picos de de tasa de bits.
Cada Carrier es llamada Carrier Component (C.C)



Existen variantes de C.A y combinaciones soportadas por los diferentes UEs.
Las bandas pueden ser contiguas o no
Puede haber diferentes anchos de banda
Se ofrece en diferentes bandas y con diferencias UL y DL
El máximo es de 32 bandas de 20 MHz cada una

MEDICIONES Y SIMULACIONES

Configuraciones de parámetros bandas

Fuente Gza:
Ing. Federico Culasso

MEDICIONES Y SIMULACIONES

Configuraciones de parámetros tramas

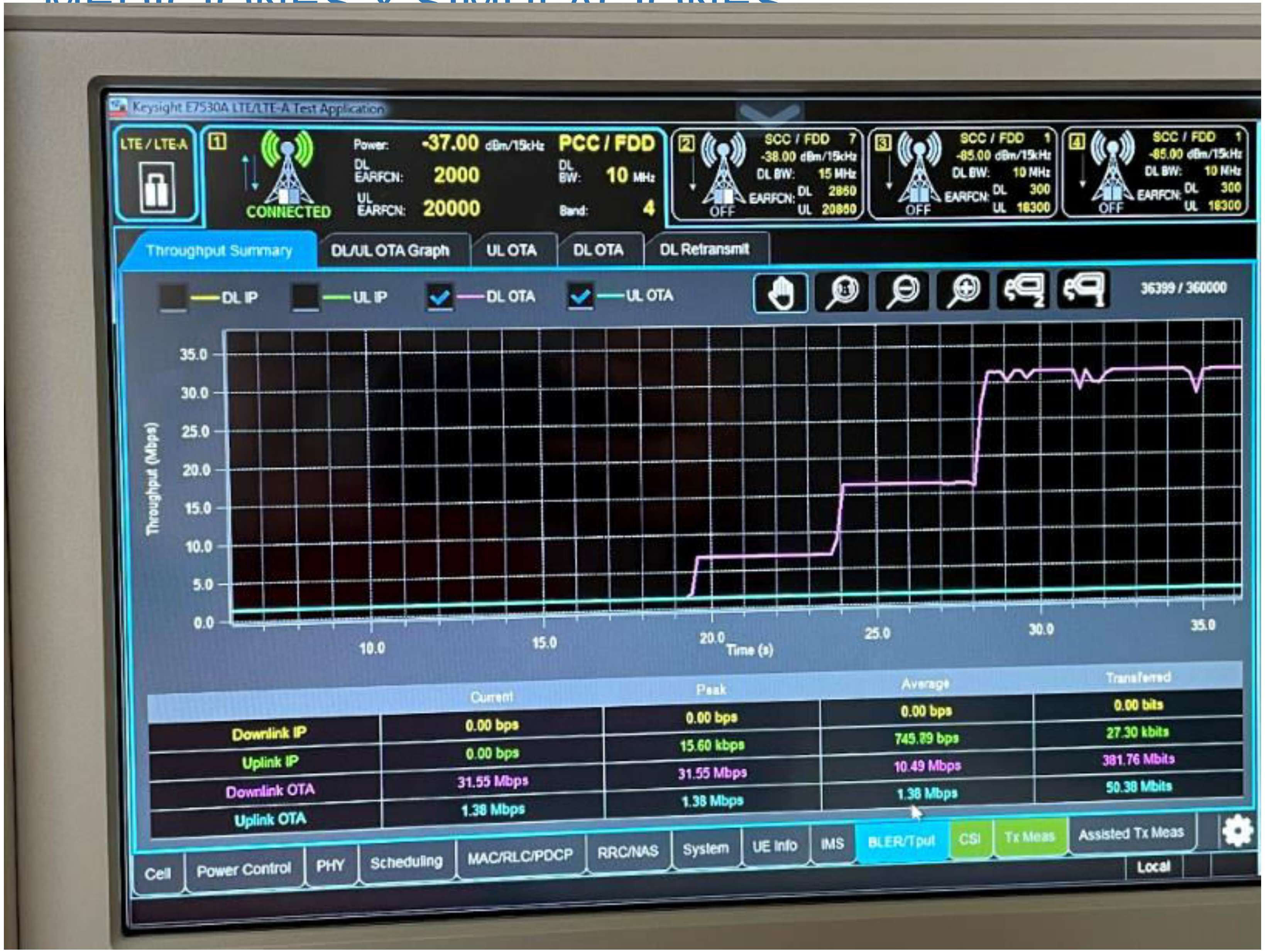
Fuente Gza:
Ing. Federico Culasso

CePETel
Sindicato de los Profesionales de las Telecomunicaciones

SECRETARÍA TÉCNICA

IPEI

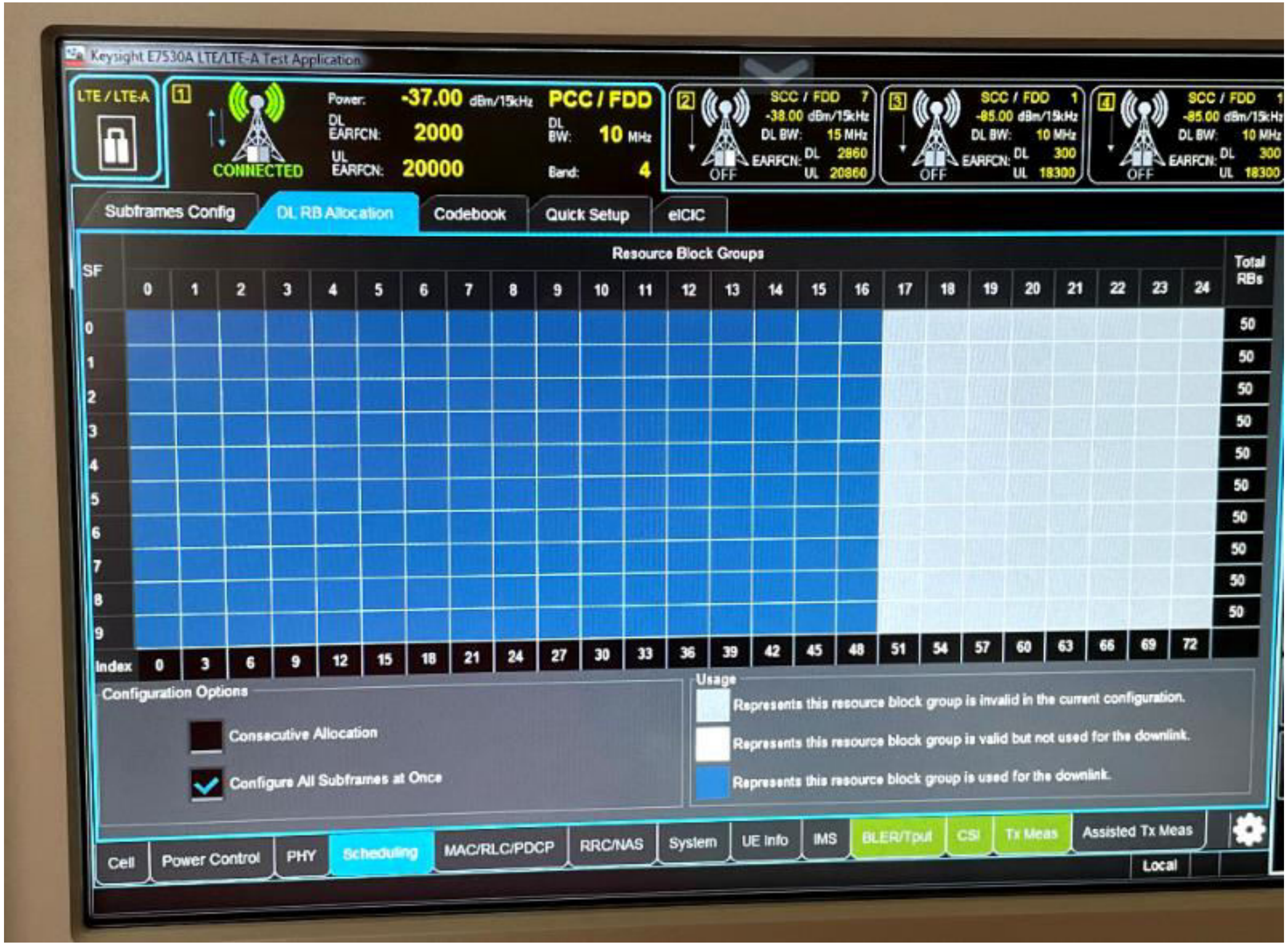
Prof. José Luis Pellegrino



Visuaización de tráfico
DL y UL

Fuente Gza:
Ing. Federico Culasso

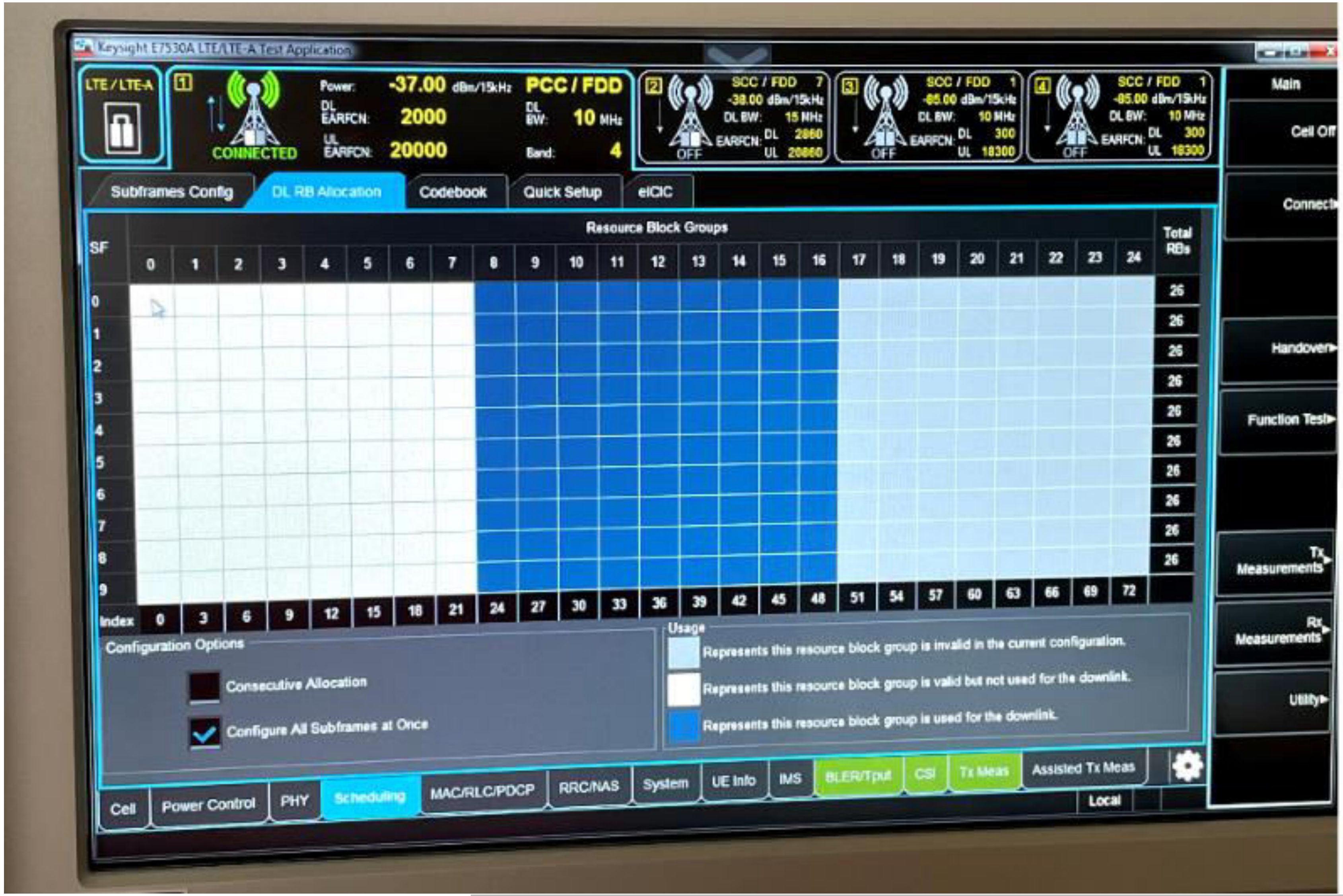
MEDICIONES Y SIMULACIONES



Configuración de RB

Fuente Gza:
Ing. Federico Culasso

MEDICIONES Y SIMULACIONES



Configuración de RB

Fuente Gza:
Ing. Federico Culasso

MEDICIONES Y SIMULACIONES

Configuración de CA

Fuente Gza:
Ing. Federico Culasso

MEDICIONES Y SIMULACIONES

Configuración de CA

Fuente Gza:
Ing. Federico Culasso

CARRIER AGREGATION EN 5G

New Radio: 16 CCs
Max channel bandwith:
- 100 MHz on lower frequency bands
- 400 MHz on mm wave frequency bands

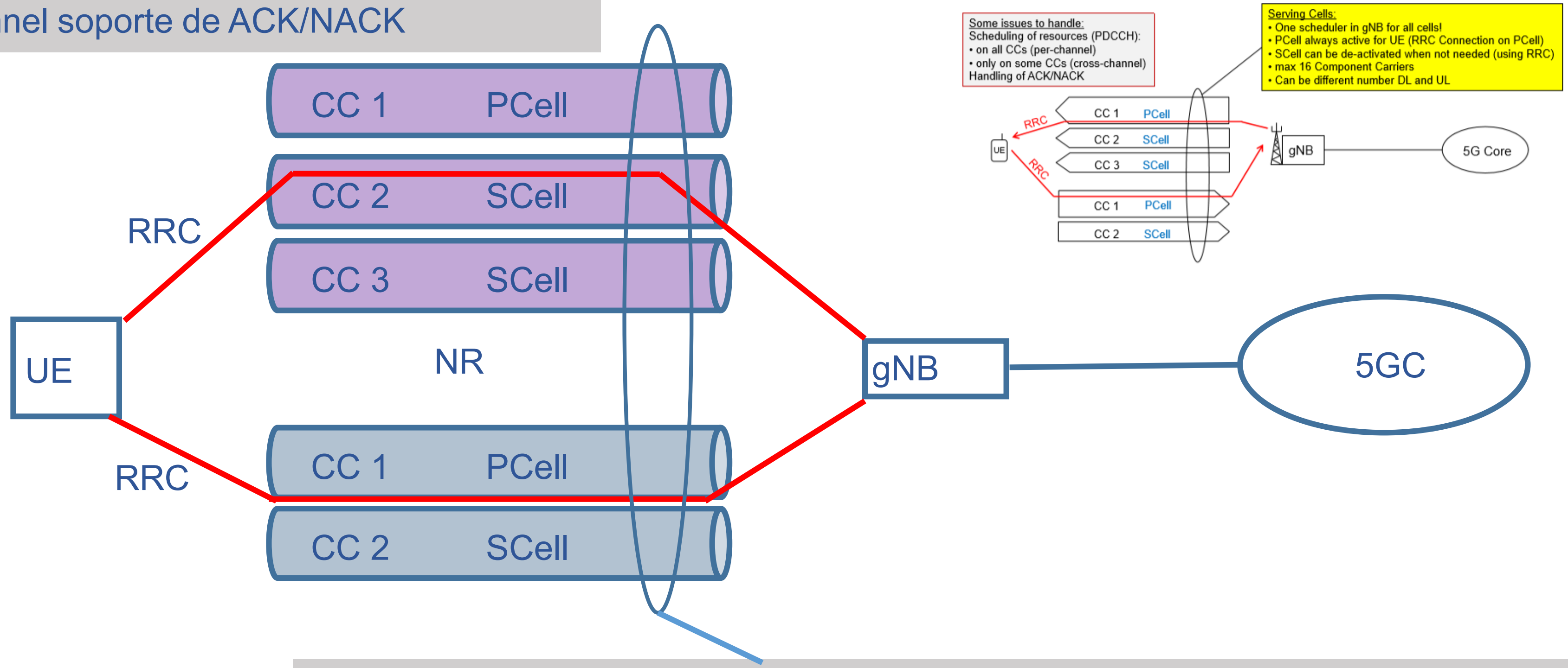
Existen variants de C.A y combinaciones soportadas por los diferentes UEs.
Las bandas pueden ser contiguas o no
Puede haber diferentes anchos de banda
Se ofrece en diferentes bandas y con diferencias UL y DL

CARRIER AGREGATION EN 5G

Algunas cuestiones a tener en cuenta:

El scheduling de recursos (PDCCH):

- En todas las CCs (por canal)
- Solo en algunas CCs (cross-channel soporte de ACK/NACK

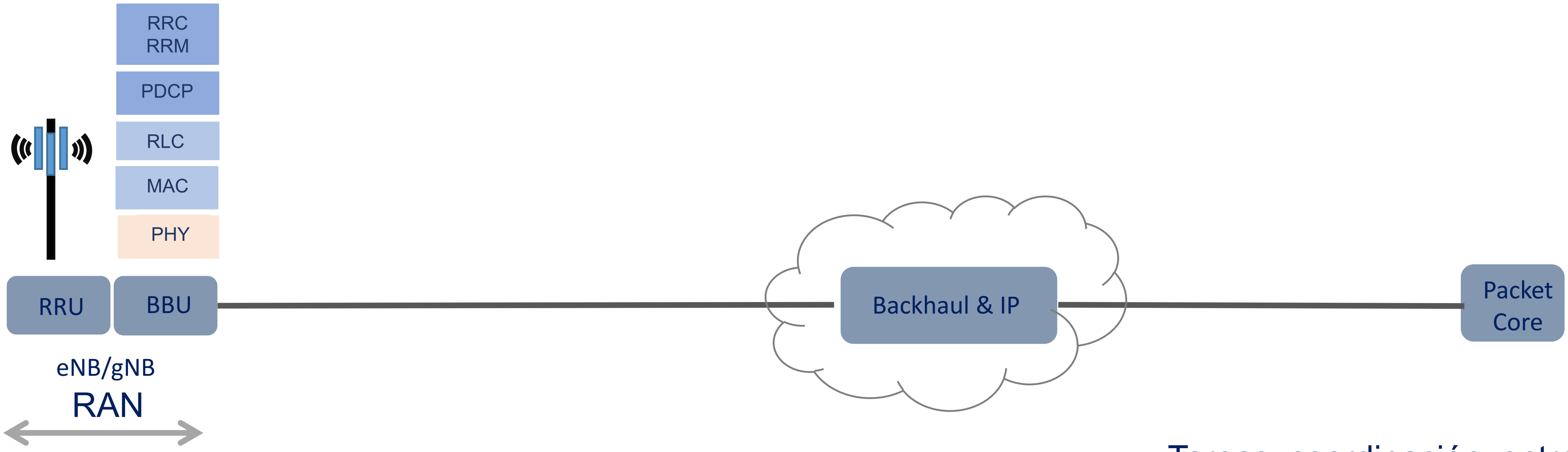


Celdas de Servicio:

- Un scheduler en el gNB para todas las celdas
- Las celdas primarias (PCell), siempre están activas (RRC connection en la Pcell)
- Las celdas secundarias (SCell) pueden ser activadas a demanda (usando RCC)
- Máximo de 16 Component Carriers (CC)
- Puede haber distinto número de DL y UL

RAN DISTRIBUÍDA, CENTRALIZADA
CPRI

DISTRIBUTED RAN



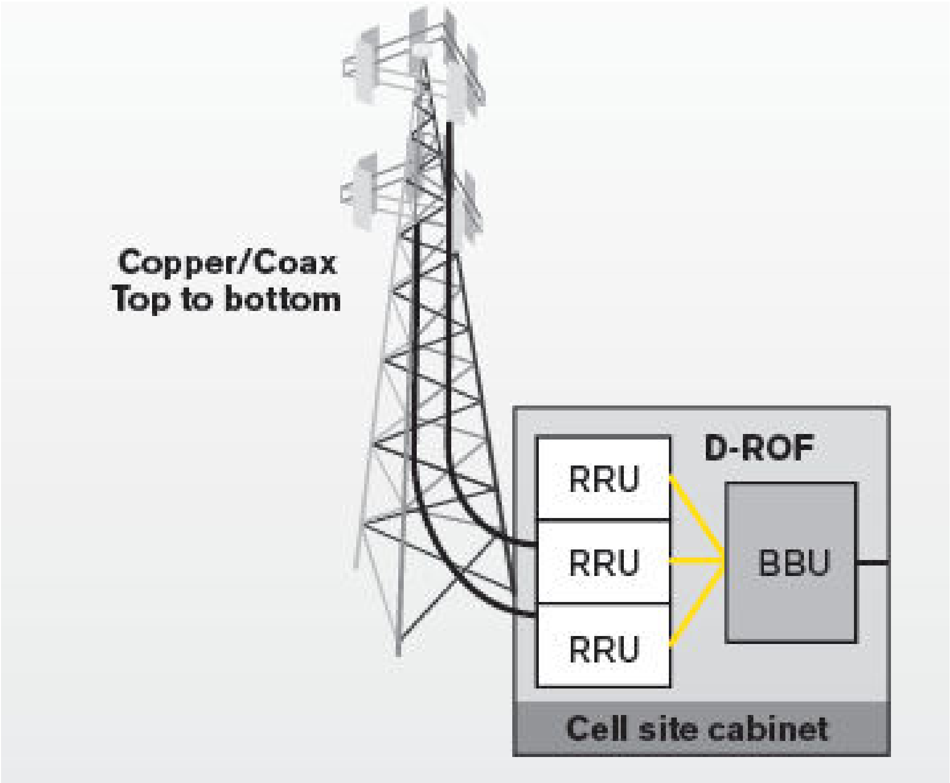
- Solución RAN provista por un solo vendor.
- Arquitectura propietaria. Interconexión RRU-Baseband propietara.
- No existe desagregación.
- SW&HW bundled.
- Limitada innovación.
- Limitada capacidad para despliegue de features inter-site.
- Dificultad para despliegue de aplicaciones de uso intensivo de cómputo.
- Solución baremetal.

Tareas coordinación entre radio bases es limitada (Interfaz X2 de LTE).

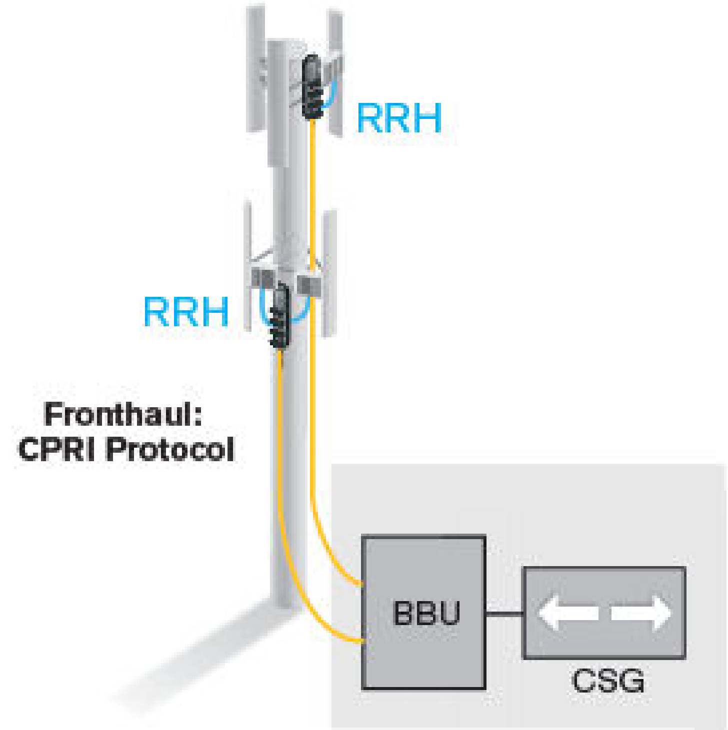
Discutir escenarios donde el modelo distribuído es mas común

DISTRIBUTED RAN

Tradicional



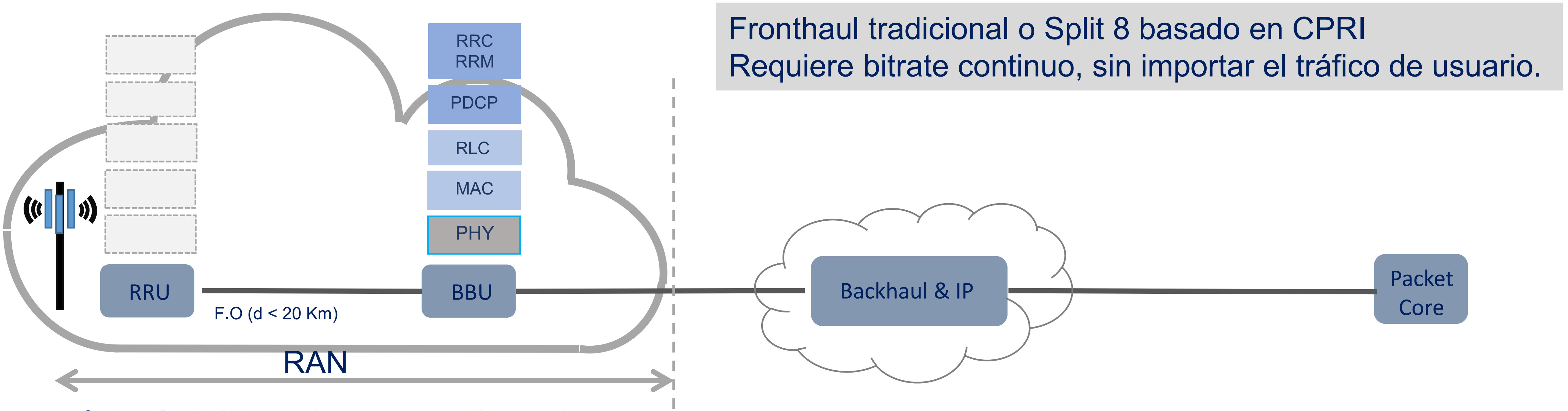
Separación de BBU y Radio



Fuente: EXFO

Tanto la BBU como la Radio siguen estando en la misma locación del sitio

CENTRALIZED RAN

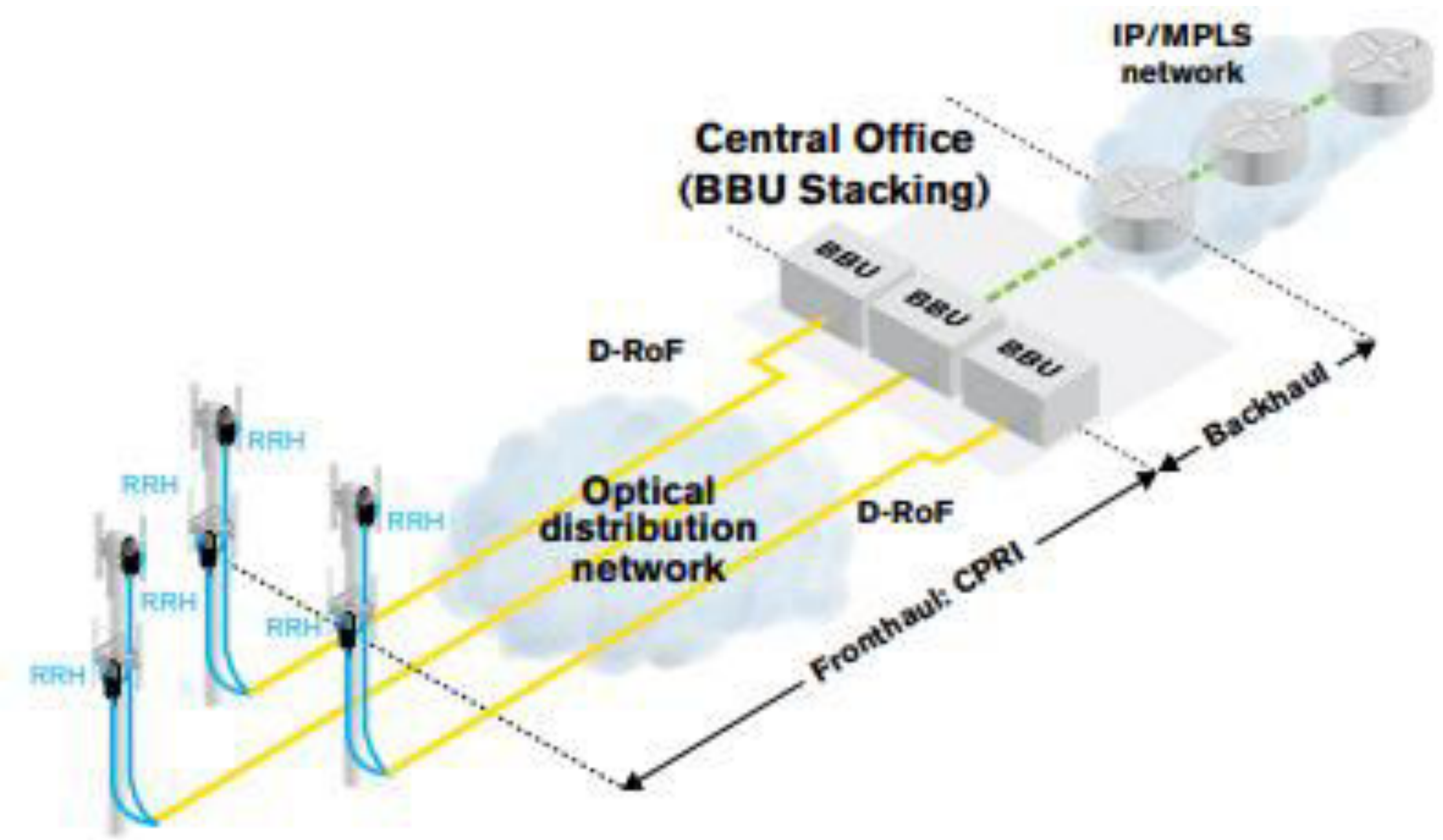


- Solución RAN provista por un solo vendor.
- El máximo grado de desagregación de la RAN es RRU y BBU (modelo granjeado)
- Pool de BBUs en un mismo lugar. BBUs colocalizadas en una central
- RAN localizada en el edge y Packet Core centralizado.
- Solo la capa de radio en el sitio.
- Todas las capas de radio desplegadas en un entorno < 20 kms (Fronthaul).
- Se simplifica el backhaul y el sincronismo
- Solución baremetal.
- CPRI propietario

eNB = RRU +BBU

Sigue siendo válido en 5G?

CENTRALIZED RAN



Tanto la BBU como la Radio siguen estando en la misma locación del sitio

CENTRALIZED RAN

A **remote radio head** (RRH), also called a **remote radio unit** (RRU) in wireless networks, is a remote radio transceiver that connects to an operator radio control panel via electrical or wireless interface.

In wireless system technologies such as GSM, CDMA,UMTS,LTE the radio equipment is remote to the BTS/NodeB/eNodeB. The equipment is used to extend the coverage of a BTS/NodeB/eNodeB in challenging environments such as rural areas or tunnels. They are generally connected to the BTS/NodeB/eNodeB via a fiber optic cable using Common Public Radio Interface (CPRI) protocols.

Common Public Radio Interface (**CPRI**) standard defines a flexible interface between Radio Equipment Controllers (REC) and Radio Equipment (RE).

REC = DU (=BBU).

RE = RU (=RRH).

CPRI

CPRI (Common Public Radio Interface) es un protocolo desarrollado EN 2003 por la industria de BTS (Ericsson, Nokia Siemens Networks, Alcatel Lucent, NEC, and Huawei Technologies) a fin de enlazar la unidad de radio (RU/RRU), con la unidad banda base (BU/BBU). La aspiración original fue especificar un protocolo standard, sin embargo todos los casos de uso son monovendor.

CPRI Specification V7.0 (2015-10-09)

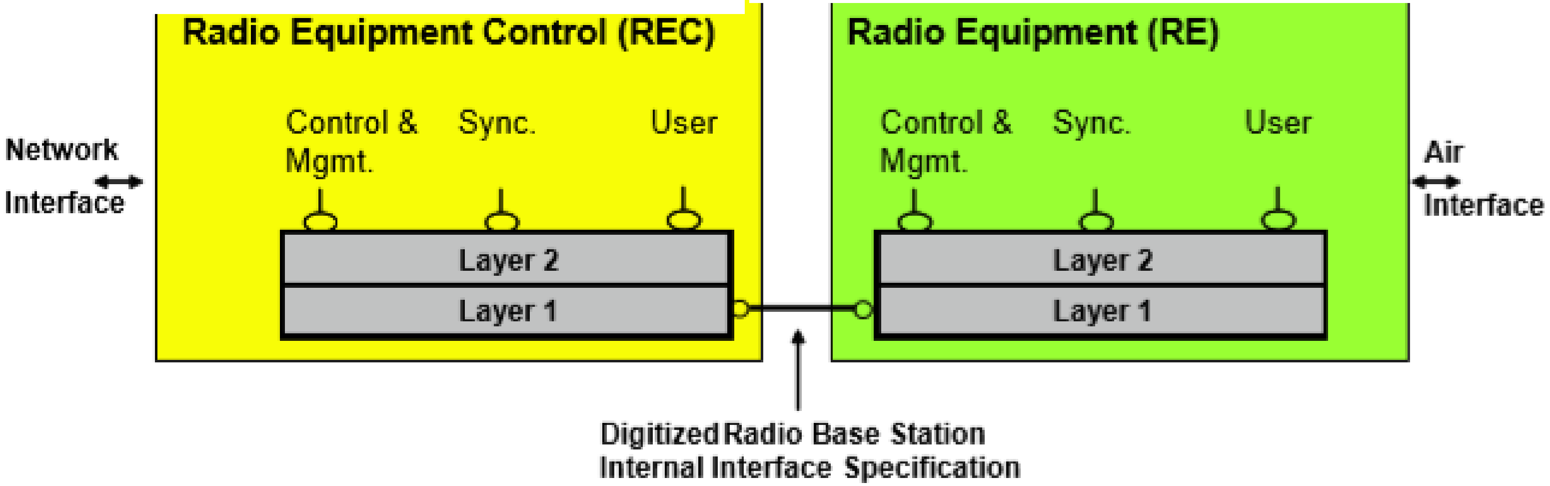
Interface Specification

Common Public Radio Interface (CPRI); Interface Specification

eCPRI Specification V1.2 (2018-06-25)

Interface Specification

Common Public Radio Interface: eCPRI Interface Specification



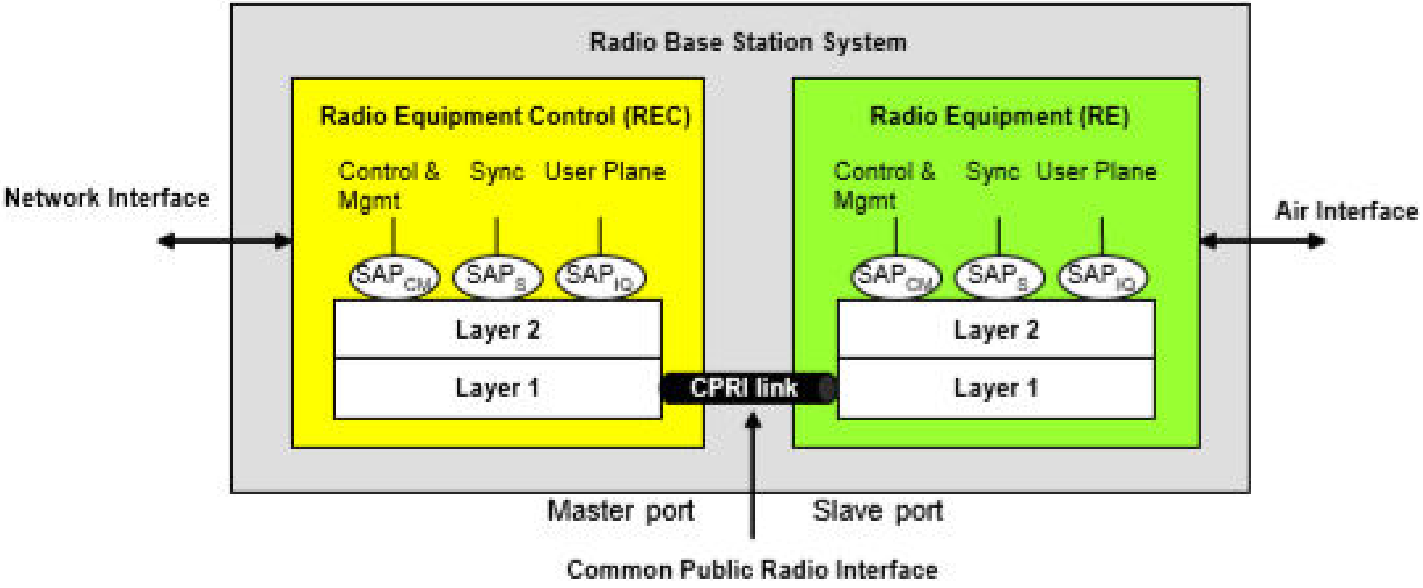
CPRI

La especificación de CPRI:

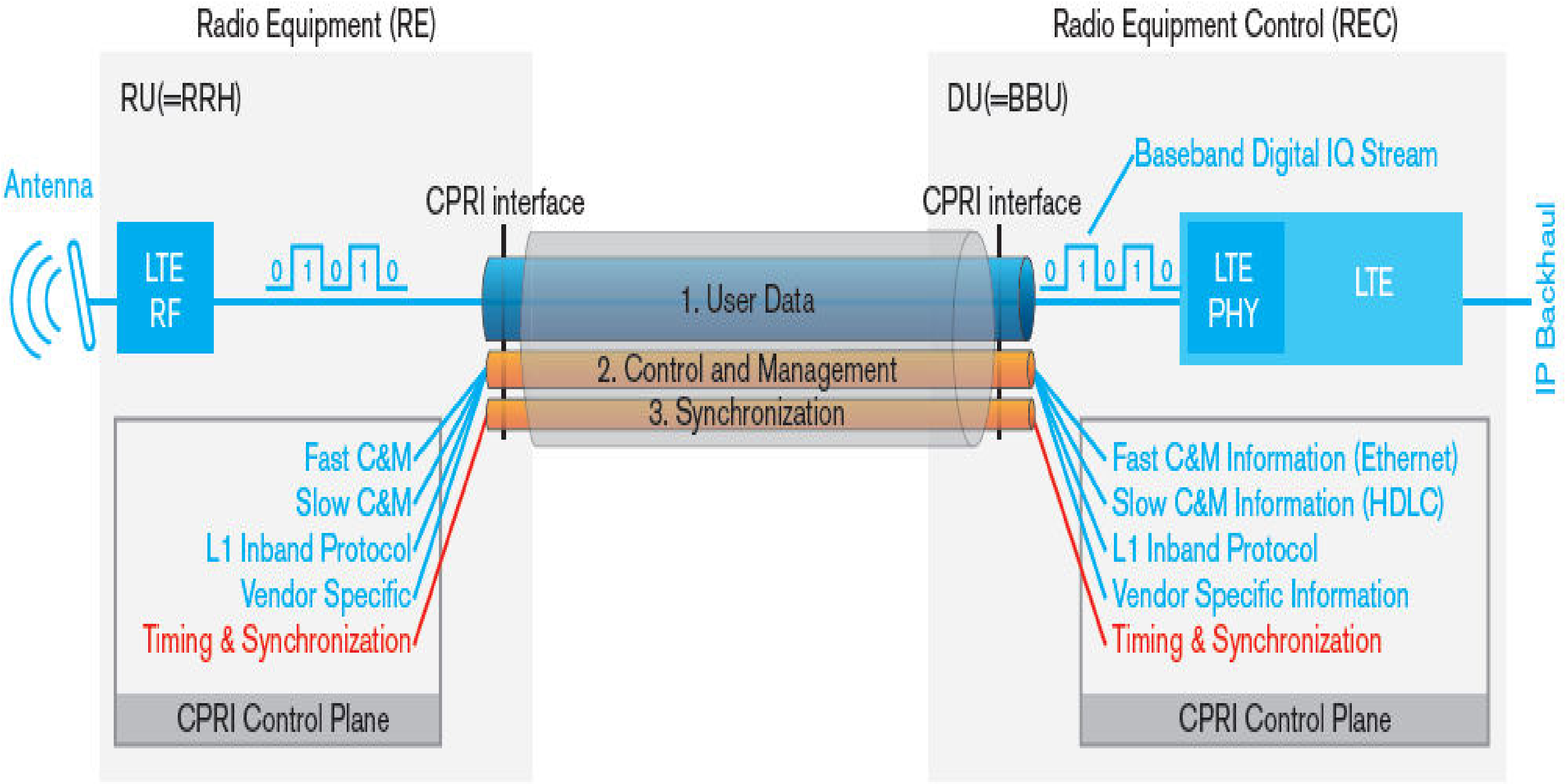
1. Una interfaz digital de radio base que establece una conexión entre el 'Control de equipo de radio' (REC) y el 'Equipo de radio' (RE) que incluye topologías de un solo salto y de múltiples saltos.
2. Se multiplexan tres flujos de información diferentes (datos del plano de usuario, datos del plano de control y gestión y datos del plano de sincronización) a través de la interfaz.
3. La especificación cubre las capas 1 y 2.

   3a. **La capa física (capa 1)** admite tanto una interfaz eléctrica (por ejemplo, lo que se usa en estaciones base de radio tradicionales) como una interfaz óptica (por ejemplo, para estaciones base de radio con equipo de radio remoto).

   3b. **La capa 2** admite flexibilidad y escalabilidad



CPRI

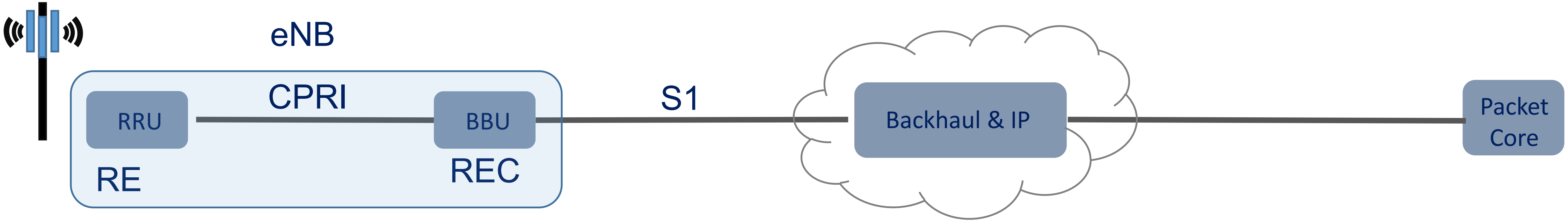


Radio Equipment (RE)
Radio Equipment Control (REC)
RU(=RRH)
DU(=BBU)
Antenna
Baseband Digital IQ Stream
CPRI interface
CPRI interface
LTE
RF
0 1 0 1 0
1. User Data
2. Control and Management
3. Synchronization
0 1 0 1 0
LTE
PHY
LTE
IP Backhaul
Fast C&M
Slow C&M
L1 Inband Protocol
Vendor Specific
Timing & Synchronization
CPRI Control Plane
Fast C&M Information (Ethernet)
Slow C&M Information (HDLC)
L1 Inband Protocol
Vendor Specific Information
Timing & Synchronization
CPRI Control Plane

CPRI

El REC contiene las funciones de radio del dominio de banda base digital, mientras que el RE contiene las funciones de radiofrecuencia analógicas. La división funcional entre ambas partes se realiza de tal manera que se puede definir una interfaz genérica basada en datos en fase y cuadratura (IQ).

En E-UTRA, el REC proporciona acceso al núcleo de paquetes evolucionado para el transporte del tráfico del plano de usuario y del plano de control a través de la interfaz S1, mientras que el RE sirve como interfaz aérea para el equipo del usuario.

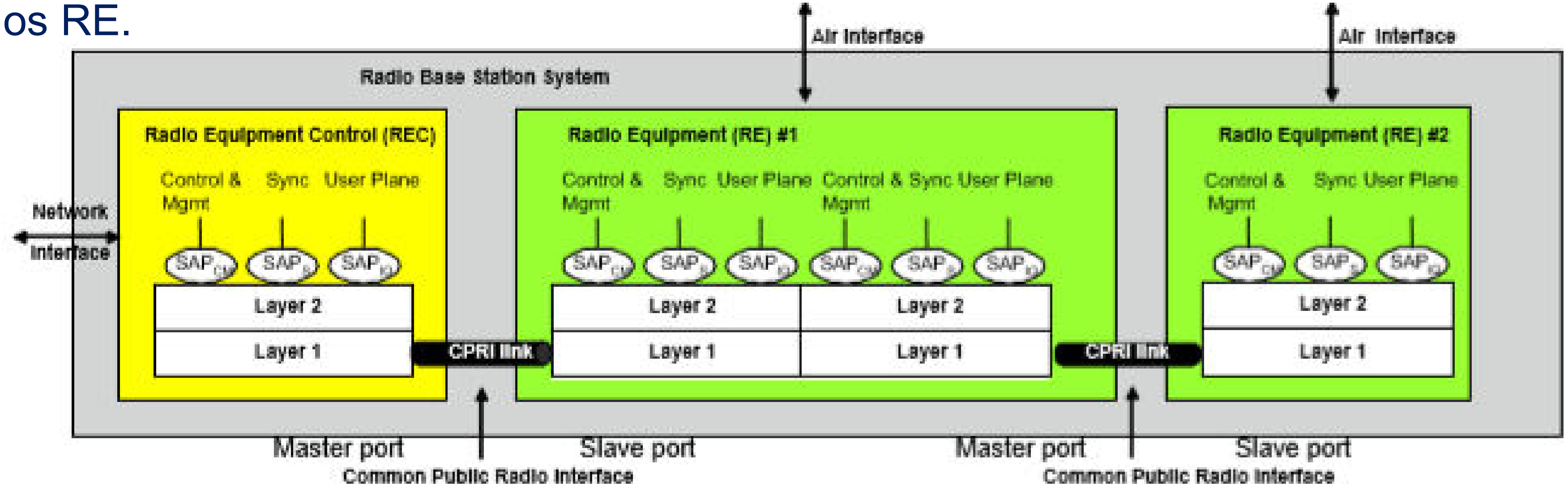


Tanto los datos del plano de usuario (***datos IQ***), las señales de ***control y gestión***, así como las señales de ***sincronización***, deben intercambiarse entre el REC y el RE.

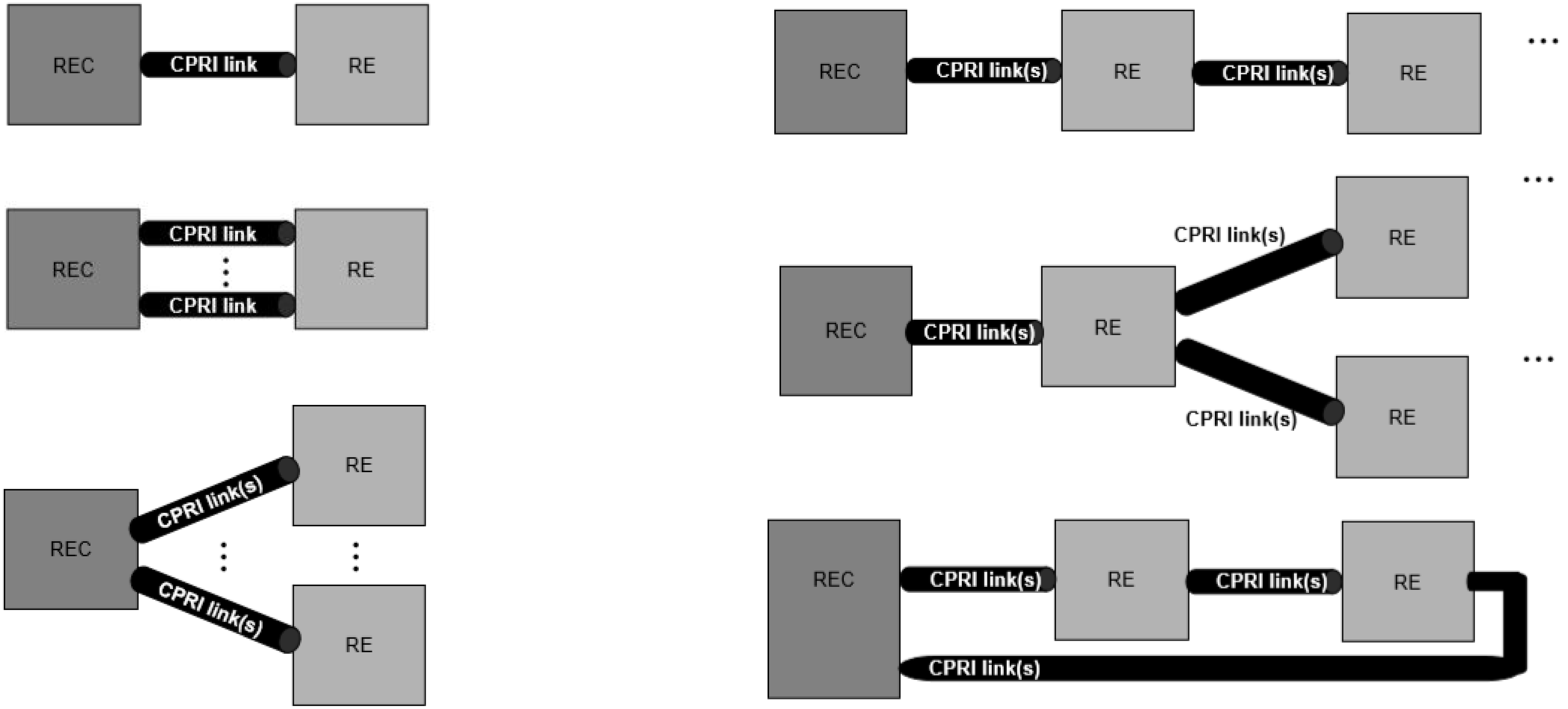
Todos los flujos de información se multiplexan en una línea de comunicación en serie digital utilizando los protocolos de capa 1 y 2 apropiados.

Los diferentes flujos de información tienen acceso a la capa 2 a través de los puntos de acceso al servicio adecuados.

La interfaz radioeléctrica pública común también se puede utilizar como enlace entre dos nodos en arquitecturas de sistemas que soportan redes. Un ejemplo de una interfaz radioeléctrica pública común entre dos RE.



CONFIGURACIONES-TOPOLOGÍAS



Fuente: Especificación CPRI

Qué tienen en común todas estas topología?

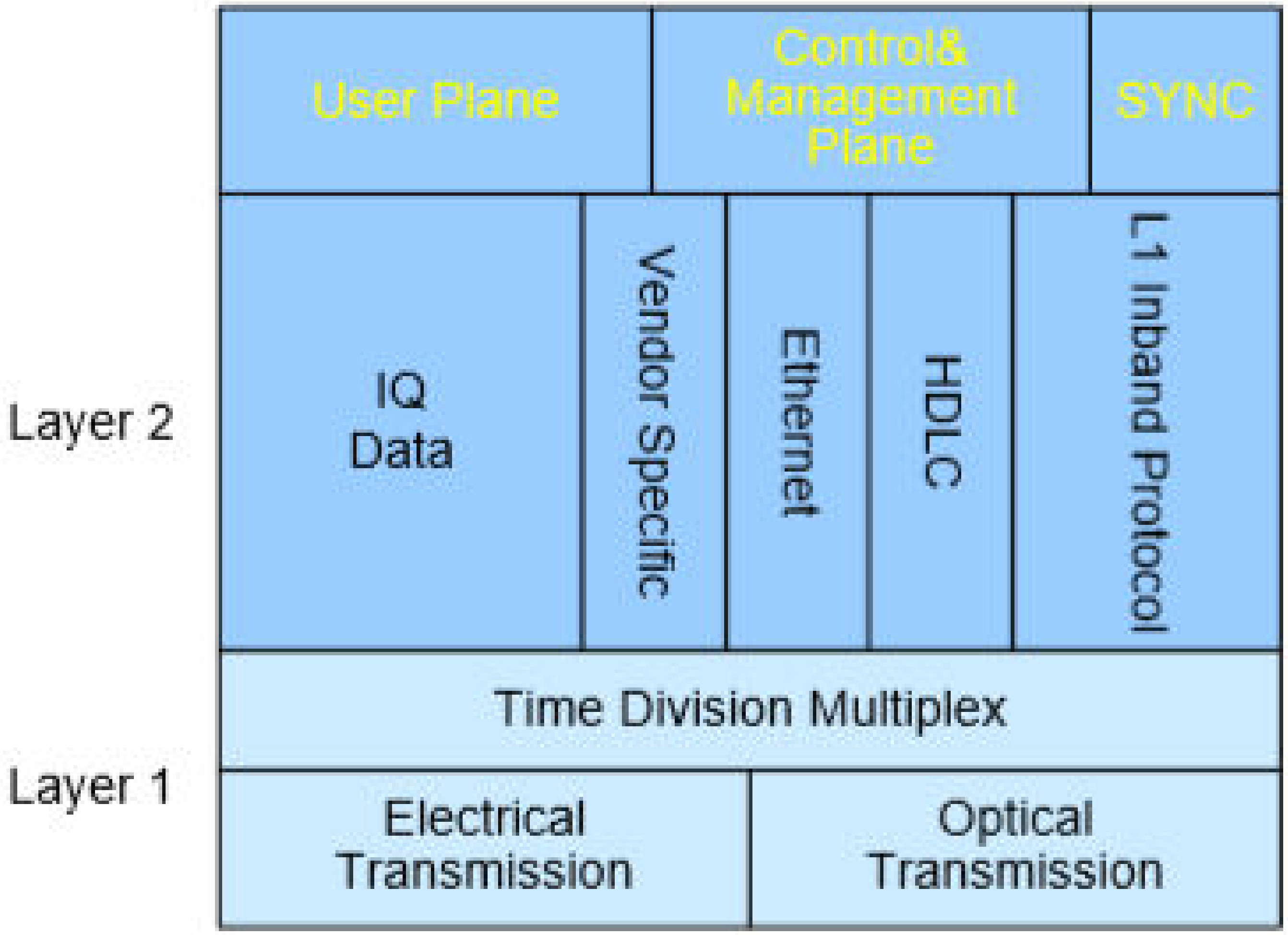
DESCRIPCIÓN FUNCIONAL

Table 1A: Functional decomposition between REC and RE (valid for WiMAX & E-UTRA)

Functions of REC		Functions of RE	
Downlink	Uplink	Downlink	Uplink
Radio base station control & management		Add CP (optional)	
Backhaul transport		Channel Filtering	
MAC layer		D/A conversion	A/D conversion
Channel Coding, Interleaving, Modulation	Channel De-coding, De-Interleaving, Demodulation	Up Conversion	Down Conversion
iFFT	FFT	ON/OFF control of each carrier	Automatic Gain Control
Add CP (optional)	Remove CP	Carrier Multiplexing	Carrier De-multiplexing
MIMO processing		Power amplification and limiting	Low Noise Amplification
Signal aggregation from signal processing units	Signal distribution to signal processing units	Antenna supervision	
Transmit Power Control of each physical channel	Transmit Power Control & Feedback Information detection	RF filtering	RF filtering
Frame and slot signal generation (including clock stabilization)		TDD switching in case of TDD mode	
Measurements		Measurements	

Fuente:
Especificación CPRI

ESPECIFICACIÓN DE LA INTERFAZ



Fuente:
Especificación CPRI

ESPECIFICACIÓN DE LA INTERFAZ

- **IQ Data:**

User plane information in the form of **in-phase and quadrature** modulation data (digital baseband signals).

- **Synchronization:**

Synchronization data used for frame and time alignment.

- **L1 Inband Protocol:**

Signalling information that is related to the link and is directly transported by the physical layer. This information is required, e.g. for system start-up, layer 1 link maintenance and the transfer of time critical information that has a direct time relationship to layer 1 user data.

- **C&M data:**

Control and management information exchanged between the control and management entities within the REC and the RE. This information flow is given to the higher protocol layers.

- **Protocol Extensions:**

This information flow is reserved for future protocol extensions. It may be used to support, e.g., more complex interconnection topologies or other radio standards.

- **Vendor Specific Information:**

This information flow is reserved for vendor specific information.

.Señales I & Q: como trasnformar un problema de fase y amplitude en un problema de amplitude!!!

ESPECIFICACIÓN DE LA INTERFAZ

In order to achieve the required flexibility and cost efficiency, several different line bit rates are defined. Therefore, the CPRI line bit rate may be selected from the following option list:

- CPRI line bit rate option 1: 614.4 Mbit/s, 8B/10B line coding (1 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 2: 1228.8 Mbit/s, 8B/10B line coding (2 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 3: 2457.6 Mbit/s, 8B/10B line coding (4 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 4: 3072.0 Mbit/s, 8B/10B line coding (5 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 5: 4915.2 Mbit/s, 8B/10B line coding (8 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 6: 6144.0 Mbit/s, 8B/10B line coding (10 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 7: 9830.4 Mbit/s, 8B/10B line coding (16 x 491.52 x 10/8 Mbit/s)
- CPRI line bit rate option 7A: 8110.08 Mbit/s, 64B/66B line coding (16 x 491.52 x 66/64 Mbit/s)
- CPRI line bit rate option 8: 10137.6 Mbit/s, 64B/66B line coding (20 x 491.52 x 66/64 Mbit/s)
- CPRI line bit rate option 9: 12165.12 Mbit/s, 64B/66B line coding (24 x 491.52 x 66/64 Mbit/s)
- CPRI line bit rate option 10: 24330.24 Mbit/s, 64B/66B line coding (48 x 491.52 x 66/64 Mbit/s)

Fuente: Especificación CPRI

Option 9: 12165.12 Mbit/s, option 10: 24330.24 Mbit/s Es suficiente?

.Que pasa con el throughput en redes 5G?

ESPECIFICACIÓN DE LA INTERFAZ

The length of a basic frame is 1 TC = 1/fc = 1/3.84 MHz = 260.416667ns. A basic frame consists of 16 words with index W=0…15. The length T of the word depends on the CPRI line bit rate as shown inTable 3.

Each bit within a word is addressed with the index B, where B=0 is the LSB and B=T-1 is the MSB.

Each BYTE within a word is addressed with the index Y, where B=0 is LSB of Y=0, B=7 is MSB of Y=0, B=8 is LSB of Y=1, etc...

The first TCW bits of the word with index W=0 are used for one control word. If TCW is not equal to T, the remaining (T-TCW) bits of the word with index W=0 are for real time vendor specific usage (according to section 7.1.4.4 real time vendor specific usage also includes U-plane IQ data transport).

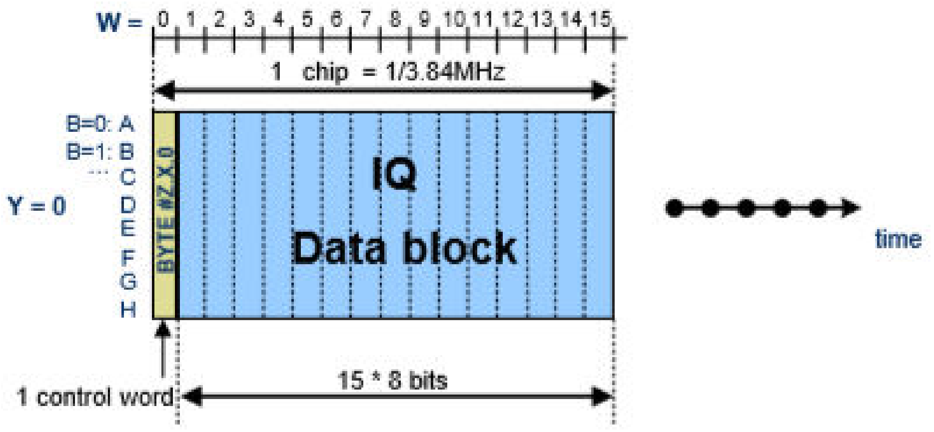


Figure 7: Basic frame structure for 614.4 Mbit/s CPRI line bit rate

Fuente: Especificación CPRI

.Que pasa con el throughput en redes 5G?

CPRI VENTAJAS Y LIMITACIONES

Limitations of CPRI

- High bandwidth (2.4 Gb/s for 2x2 MIMO, 20 MHz)
- Point-to-point direct connectivity (fiber)
- Vendor specific information (Interop nightmare)
- Massive MIMO, 5G support will require 100 Gb/s fronthaul

Ethernet based fronthaul – eCPRI

- Point to multipoint
- Ethernet protocol stack
- Huge ethernet market
- Split optimization for fronthaul bandwidth reduction
- Solves OAM interoperability for multi-vendor deployment

eCPRI used between DU and RRU where supported. Different architecture are possible, including cases where **RIU: Remote Interface Unit** must be used as IOT with RRU which do not support eCPRI.

CPRI VENTAJAS Y LIMITACIONES

CPRI

- Desarrollado en 2003 como interfaz común.
- Corre entre RRH y BBU.
- RRH, equivalente a RRU con split Option 8 .
- BBU es equivalente a una DU y CU combinadas.
- Transporta muestras digitales banda base del tipo "time-domain".

CPR1	614.4 Mbps
CPR2	2.457 Gbps
CPR3	9.83 Gbps
CPR4	12.165 Gbps

Ventajas:
- Simplifica los equipos en el sitio.
- Ahorra energia en el sitio, baja el OPEX .

Permitió el desarrollo del modelo C RAN lo cual fue un un paso evolutivo importante

Desventajas y limitaciones:
- Requiere conectividad directa "point-to-point"(fibra oscura).
- Ineficiente. Altos requerimientos de ancho de banda. (2.4 Gb/s for 2x2 MIMO, 20 MHz).
- No soportaría las demandas de BW en 5G, en especial con massive MIMO. mMIMO con 5G requerirá hasta 100 Gb/s fronthaul.
- Bitrate constante aún sin tráfico
- Información "Vendor especifica" (problemas de interoperabilidad).

No obstante, no es adecuado para Open RAN especialmente para 5 G

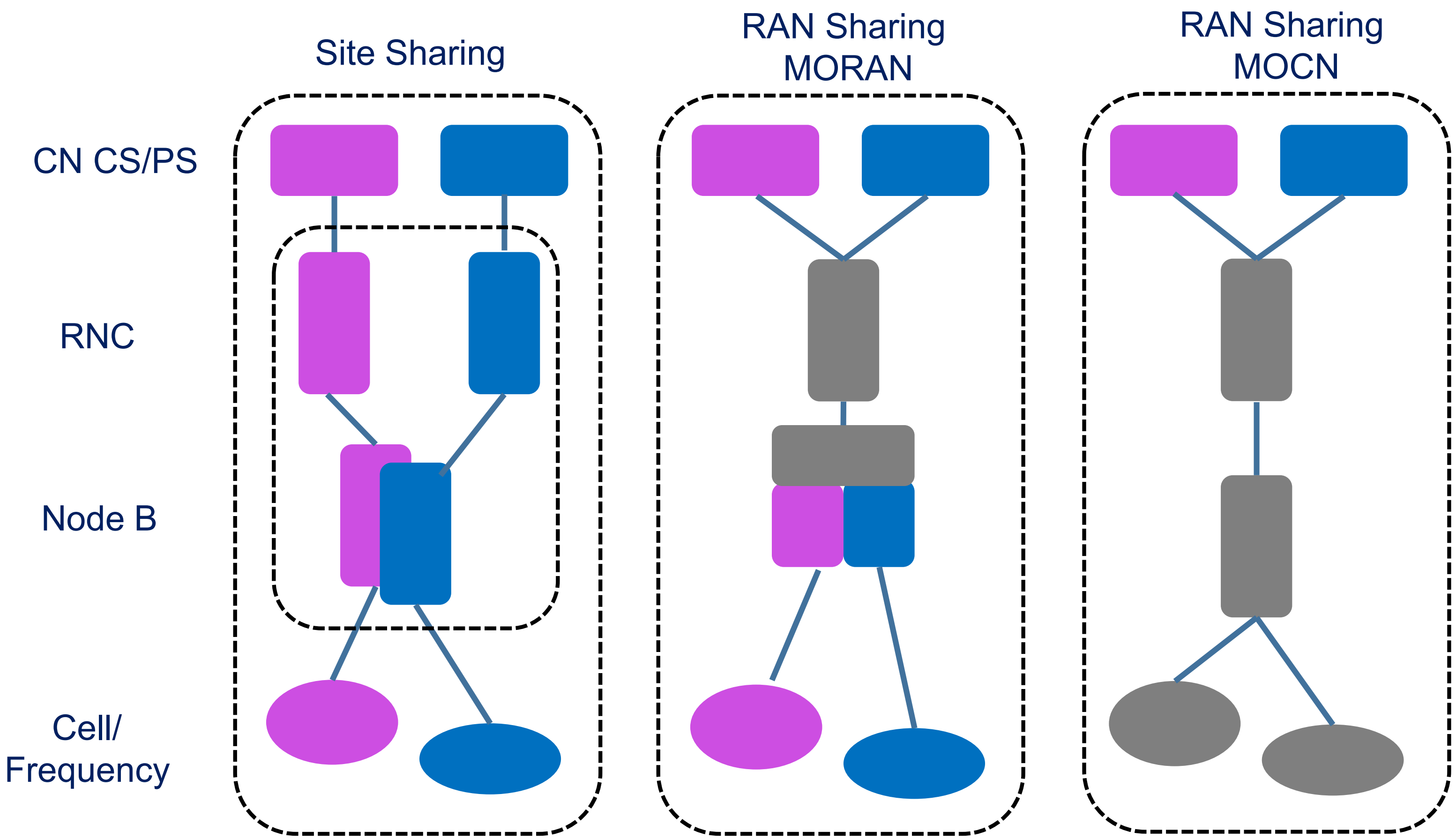
RAN SHARING

Las redes móviles operan en una infraestructura de red, que no solo se limita a componentes electrónicos, sino que también incluye elementos pasivos como sitios físicos y torres que se requieren para operar la red. A medida que la red se va densificando (esto viene de antes de 4G), compartir la infraestructura de red se está volviendo más popular. Se espera que esto continúe en la era 5G, donde las redes se densificarán aún más. El uso compartido de la red se presenta de muchas formas, pero en su mayoría se clasifica según los componentes tecnológicos que se comparten.

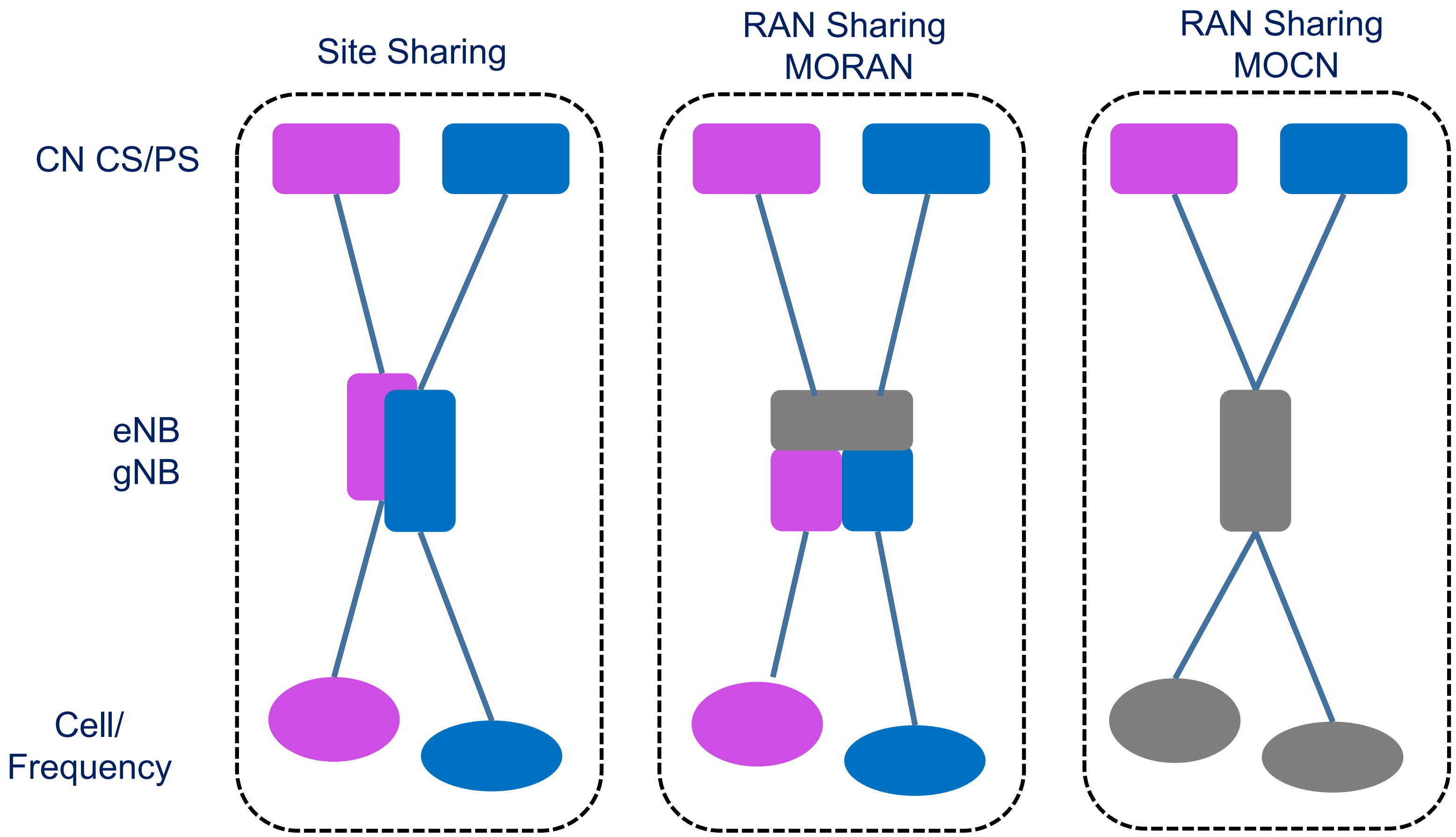
Dependiendo de qué elememtos sean compartidos, las variantes se puden clasificar en MORAN (Multi-Operator Radio Access Network), donde las redes de acceso de radio se comparten y cada operador de intercambio utiliza un espectro dedicado y MOCN ((Multi-Operator Core Network), donde se comparten las redes de acceso de radio y también el espectro.

MORAN es tecnicamente preferido, siempre que no haya limitaciones (p ejemplo que las antenas y radios adamitan la suma de los anchos de banda de cada Operador.

RAN SHARING


Site Sharing
RAN Sharing
MORAN
RAN Sharing
MOCN
CN CS/PS
RNC
Node B
Cell/
Frequency

RAN SHARING EN 4G Y 5G



REDES DE QUINTA GENERACIÓN
Curso Nivel 2
Módulo 2

CePETel

Prof. José Luis Pellegrino

MODULO 1
Arquitectura de la red de Red de Acceso.
Protocolos: Capa física, MAC, RLC, PDCP, Capas altas.
Ancho de banda asociado a cada capa.
Modelo de Centralización y de Distribución.
CPRI.

MODULO 2
Arquitectura del Núcleo en redes SA
Concepto de Slicing
Entidades, Interfaces protocolos.
Overlay 5GC con EPC

MODULO 3
La red de transporte en 5G.
Requerimientos de ancho de banda.
Requerimientos de latencia. TSN.
Desagregación de la Red de Acceso.

MODULO 4
Open RAN
Arquitectura.
Modelo
Casos y desafíos

LTE & EPC

MODULO 5

5G Signalling

NWDAF Network Data Analytics Function

SEPP Seurity Edge Protection Proxy

MODULO 6

Automatización

SDN

SON

RIC

PATRONES DE TRÁFICO

Water / gas meter

Periodic transmission, little data amount, no mobility, deep indoor locations with poor coverage
Low power consumption requirements

Burglar alarm

Spontaneous transmission, little data amount, no mobility
Possibly low power consumption requirements

Surveillance camera

Constant, high data rate transmission, no mobility
No power saving features needed

Fleet tracking device

Periodic and spontaneous data transmissions, polling from application server side
High mobility

Road traffic camera

Periodic transmission of small data amounts with possibly video stream when unusual activity (e.g. an accident) detected.

Patient health monitoring system

Periodic and spontaneous data transmissions, requests from server side, low delay tolerant transmission e.g. in case of sudden condition changes, medium mobility

Object tracking

Little or no device initiated transmissions, short response time requirements for server-side queries
High mobility, possibly low power consumption requirements

Remotely operated machinery, e.g. water valve

Little or no device initiated transmissions, short response time requirements for server-side queries
Low or no mobility, possibly low power consumption requirements

Identificar para cada caso a cual de los tres tipos corresponde

REQUERIMIENTOS DE 5G

The 5G system is characterised by:

- Support for multiple access technologies
- Scalable and customizable network
- Advanced Key Performance Indicators (KPIs) (availability, latency, reliability, user experienced data rates, area traffic capacity)
- Flexibility and programmability (e.g., network slicing, diverse mobility management, Network Function Virtualization)
- Resource efficiency (both user plane and control plane)
- Seamless mobility in densely populated and heterogeneous environment
- Support for real time and non-real time multimedia services and applications with advanced Quality of Experience (QoE)

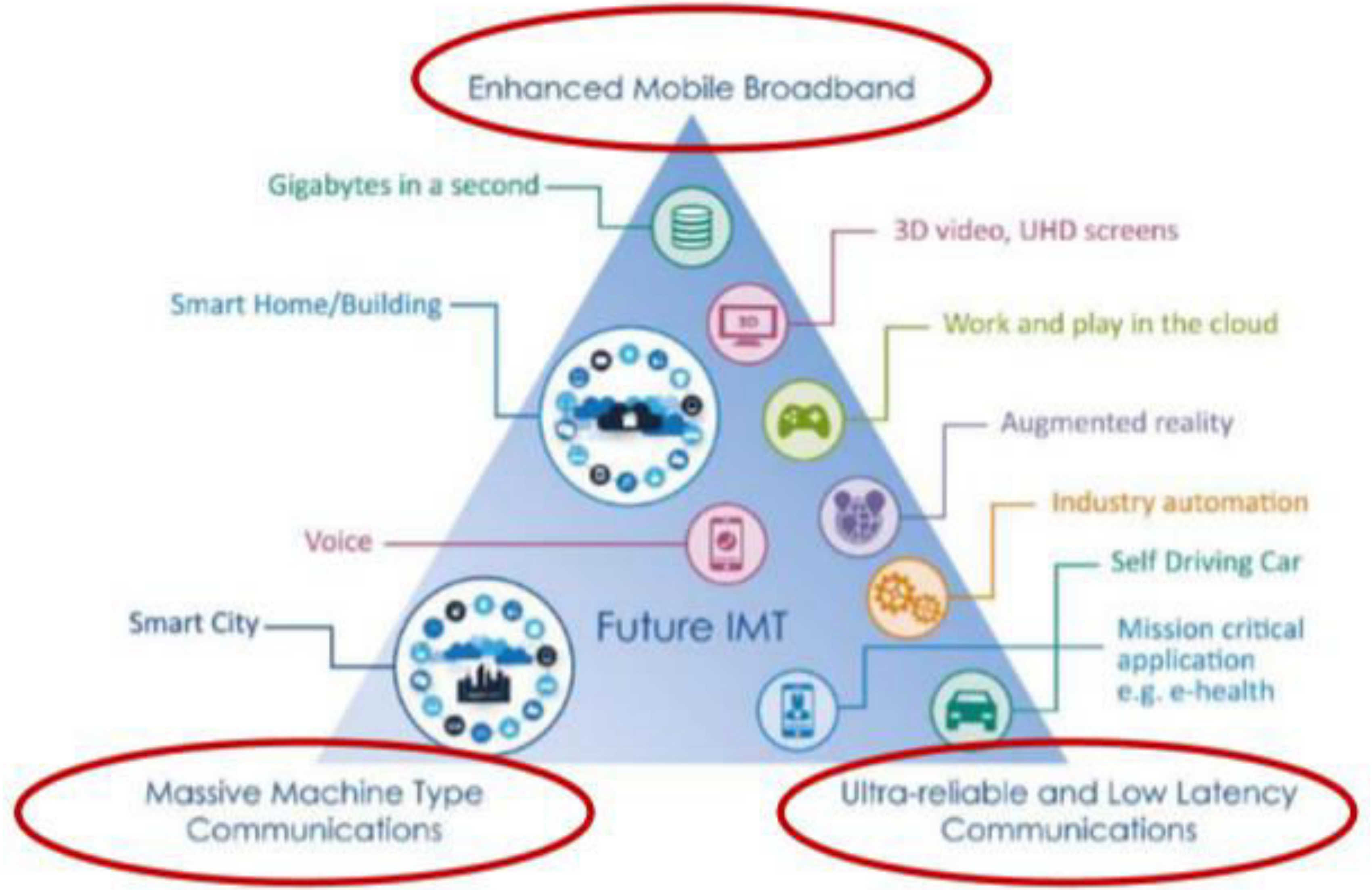
The 5G system shall support :

- The extreme long range coverage (up to 100 km) in low density areas (up to 2 user/km^2)
- A minimum user throughput of 1 Mbps on DL and 100 kbps on UL at the edge of coverage
- A minimum cell throughput capacity of 10 Mbps/cell on DL (based on an assumption of 1 GB/month/sub)
- A maximum of 400 ms E2E latency for voice services at the edge of coverage

A key feature of 5G is support for UEs with different mobility management needs. 5G will support UEs that are:

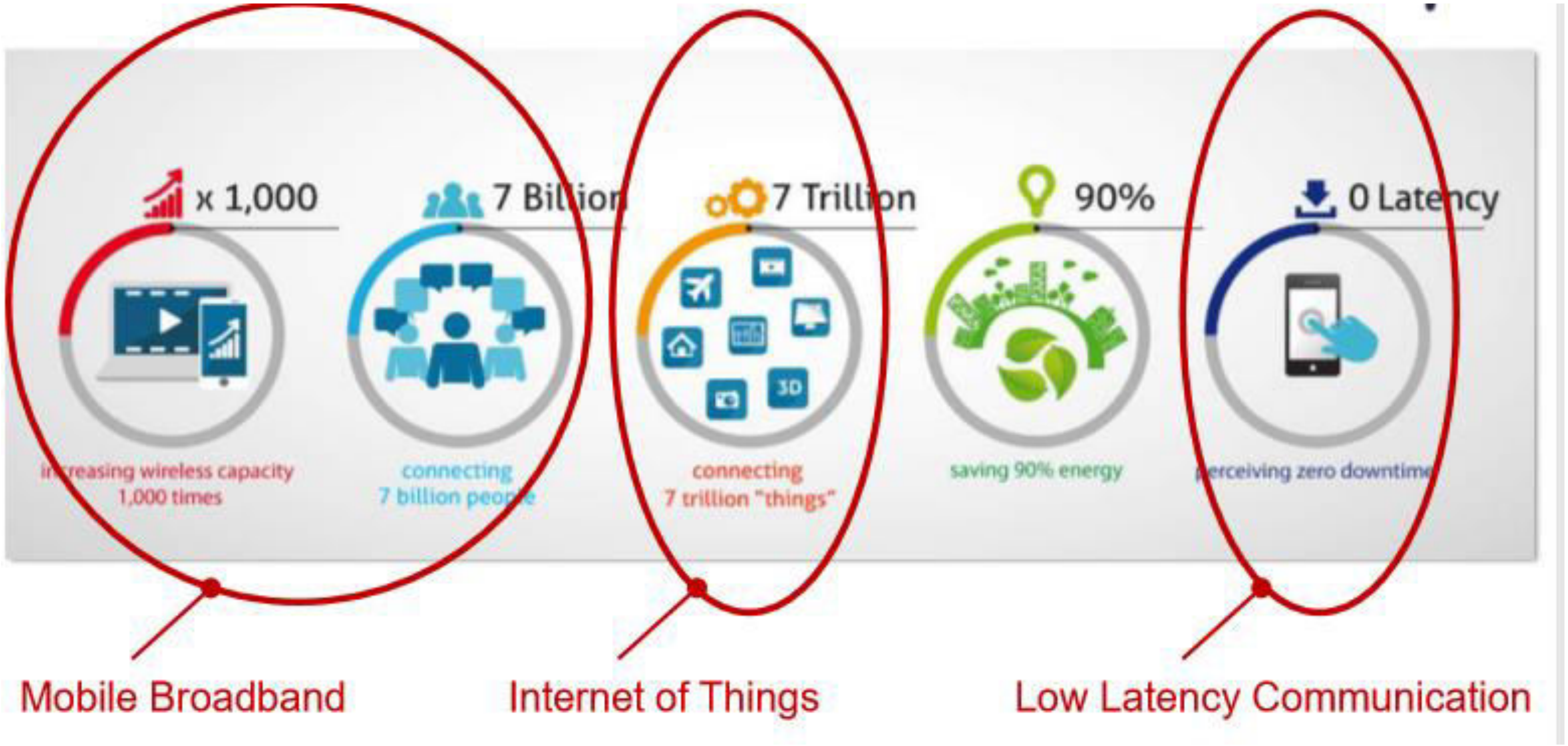
- Stationary during their entire usable life (e.g., sensors embedded in infrastructure)
- Stationary during active periods, but nomadic between activations (e.g., fixed access)
- Mobile within a constrained and well-defined space (e.g., in a factory)
- Fully mobile

CASOS DE USO



Enhanced Mobile Broadband
Gigabytes in a second
3D video, UHD screens
Smart Home/Building
Work and play in the cloud
Augmented reality
Industry automation
Voice
Self Driving Car
Smart City
Future IMT
Mission critical application e.g. e-health
Massive Machine Type Communications
Ultra-reliable and Low Latency Communications

CASOS DE USO EN NÚMEROS

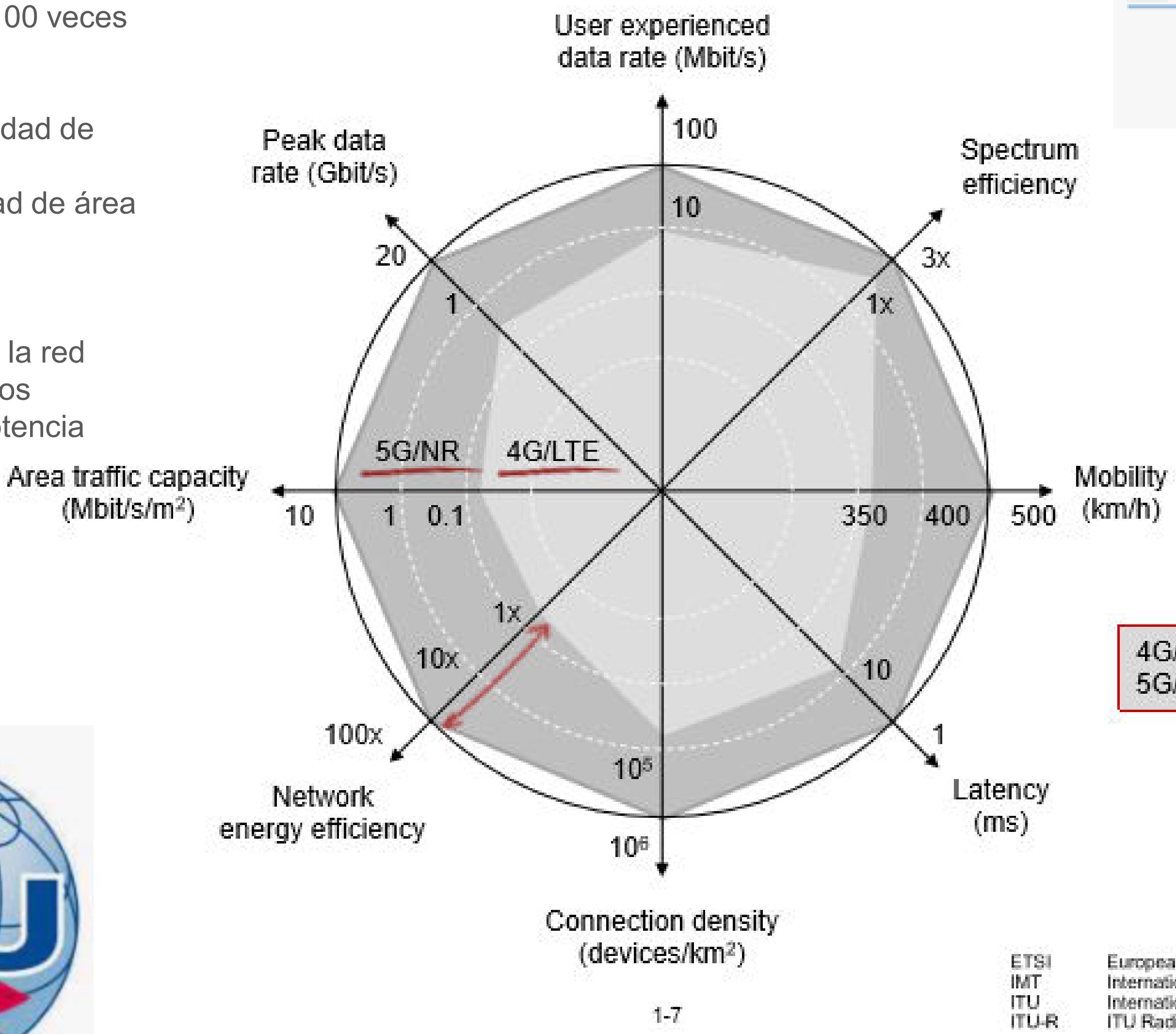


Fuente: APIS

EXPECTARTIVAS DE ETSI Y DE ITU

- Una tasa de datos de hasta 10Gbps - > de 10 a 100 veces mejor que las redes 4G y 4.5G
- Latencia de 1 milisegundo
- Una banda ancha 1000 veces más rápida por unidad de área
- Hasta 100 dispositivos más conectados por unidad de área (en comparación con las redes 4G LTE)
- Disponibilidad del 99.999%
- Cobertura del 100%
- Reducción del 90% en el consumo de energía de la red
- Hasta 10 diez años de duración de la batería en los dispositivos IoT (Internet de las Cosas) de baja potencia

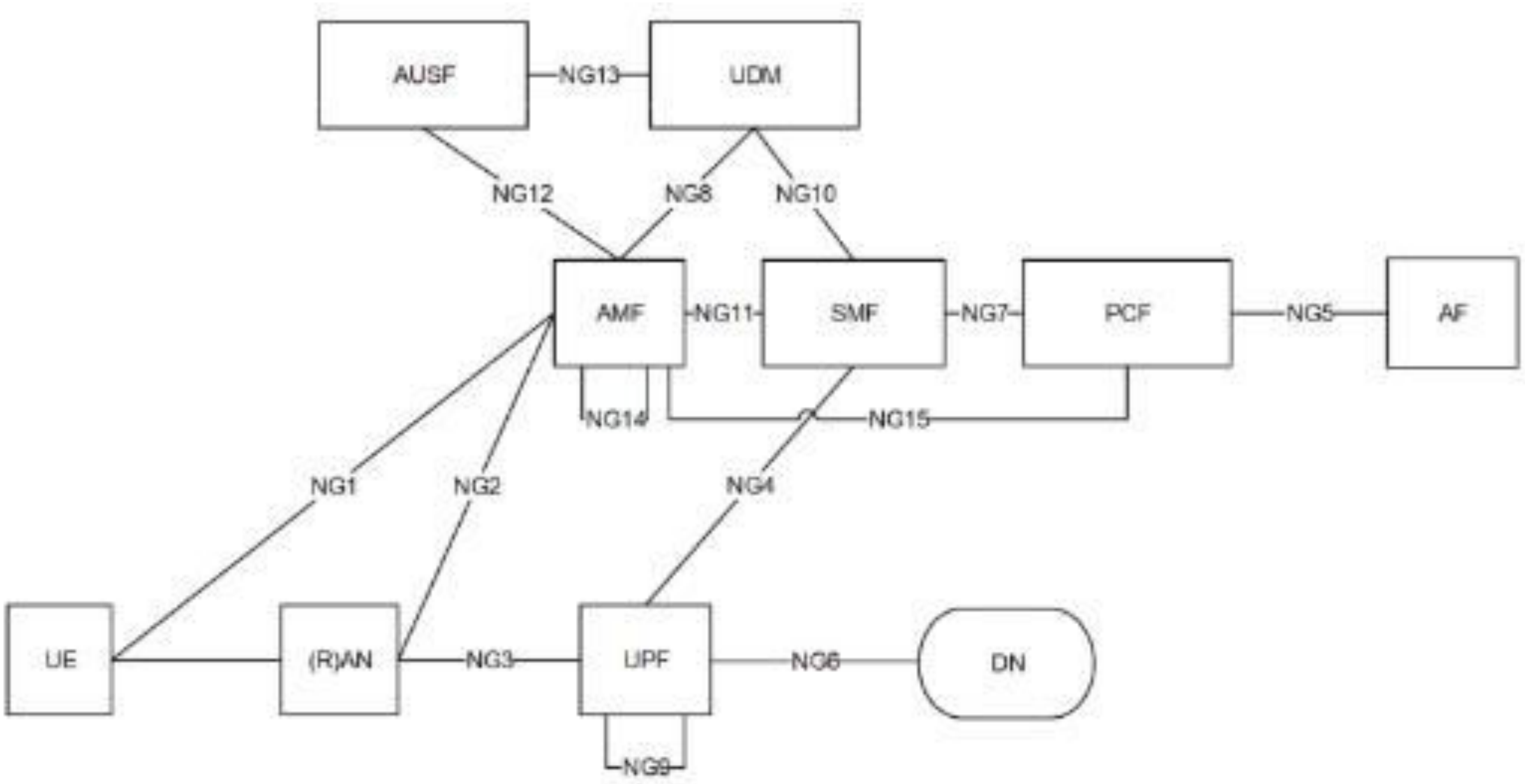
Reflexionar sobre estos indicadores



4G/LTE = "IMT Advanced"
5G/NR = "IMT-2020"

ETSI	European Telecommunications Standards Institute
IMT	International Mobile Telecommunication
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication sector

ESTRUCTURA DEL NGC



5G IDENTIDADES DE SUSCRIPCIÓN

SUPI, Subscription Permanent Identifier: identifies a subscription in the 5GS, used only within the 3GPP system. Possible formats:

1. IMSI, MCC + MNC + MSIN
2. Network Access Identifier (RFC 7542)
   - IMSI based, IMSI@nai.5gc.mnc<MNC>.mcc<MCC>.3gppnetwork.org
   - Non-IMSI based, username@realm

SUPI allocated to the 3GPP UE shall always be based on an IMSI for interworking with the EPC.

SUCI, Subscription Concealed Identifier: "Privacy preserving identifier containing the concealed SUPI". Subscription-specific part of the SUPI is encrypted, the home network information remains in cleartext for routing. UE encrypts the SUPI using a hnw-specific public key, SUCI is decrypted in the UDM using a hnw-specific private key.

5G-GUTI, 5G Globally Unique Temporary Identifier: a temporary subscription identifier allocated by the AMF. Purpose:

- Subscription identity confidentiality
- Identification of the last used AMF

<5G-GUTI> = <GUAMI><5G-TMSI>, where:

<GUAMI> = <MCC><MNC><AMF Identifier> and <AMF Identifier> = <AMF Region ID><AMF Set ID><AMF Pointer>

Common value for 3GPP and non-3GPP accesses.

GPSI, Generic Public Subscription Identifier: identifies the 3GPP subscription towards the data networks outside the 3GPP system, can also be used inside the 3GPP networks. Possible formats:

1. MSISDN
2. External Identifier, <Local Identifier>@<Domain Identifier>

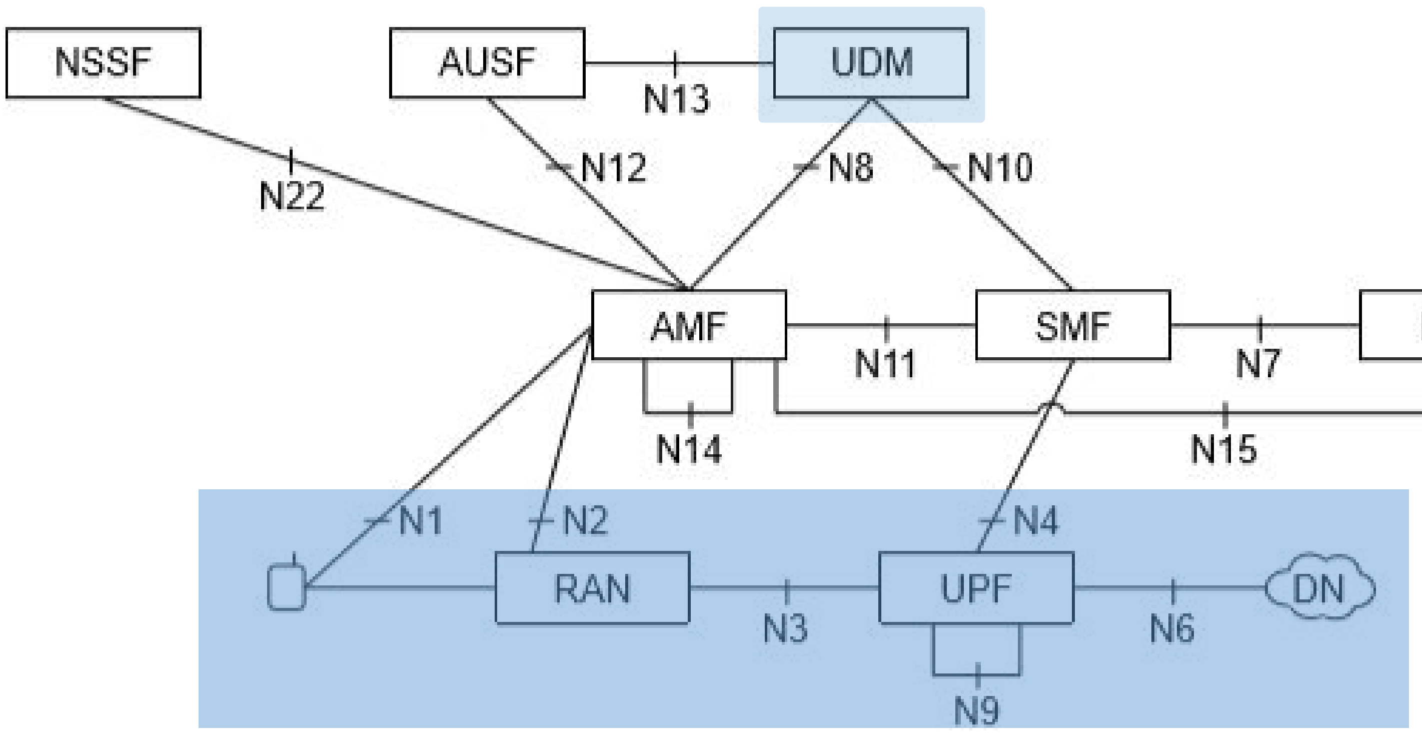
GPSI ←→ SUPI binding created in the NEF. There is no implied 1:1 relationship between the SUPI and the GPSI.

PEI, Permanent Equipment Identifier: identifies the UE, the only format in R15 is IMEI.

MNC: Mobile Network Code
MSIN Mobile Subscription Identification Number
NEF: Network Exposure Function
TMSI: Temporary Mobile Subscriber Identity
UDM: Unified Data Management

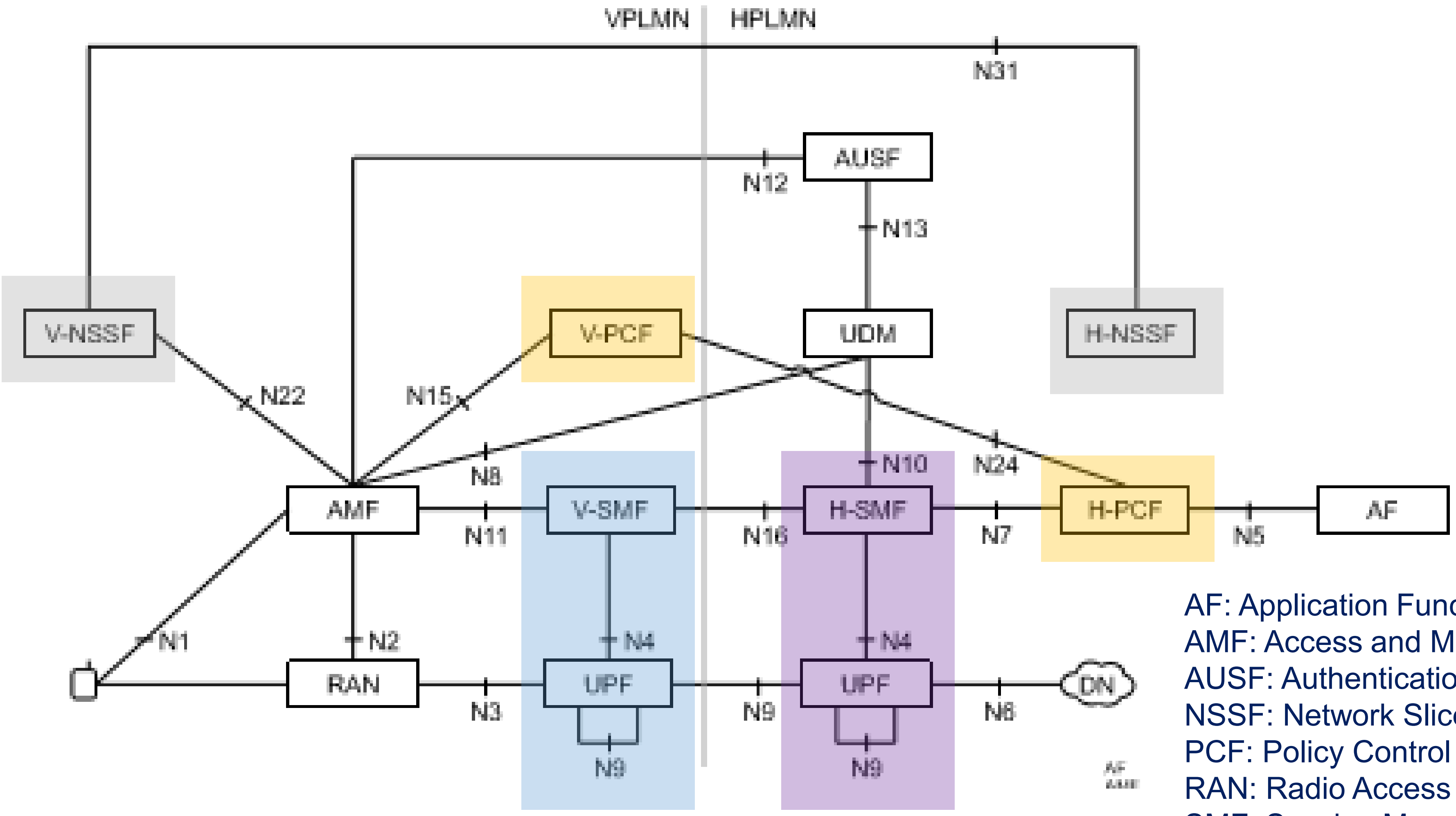
3GPP 3RD Generation Partnership Project
AMF: Access and Mobility Function
GUAMI: Globally Unique AMF Identifier
IMEI: Interntional Mobile Station Equipment Identity
MCC: Mobile Country Code

5G REPRESENTACIÓN DE PUNTOS DE REFERENCIA



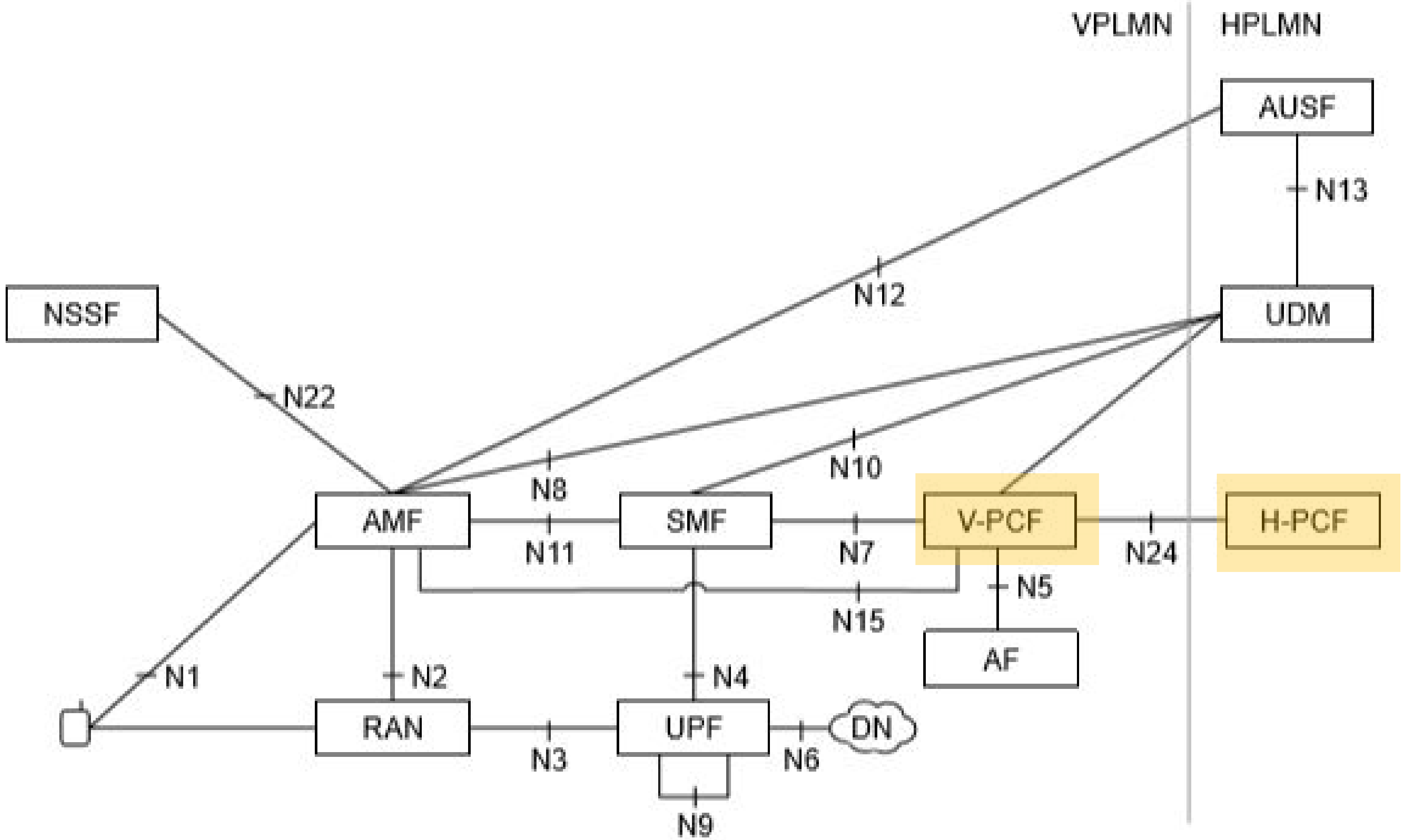
AF: Application Function
AMF: Access and Mobility Management Function
AUSF: Authentication Server Function
NSSF: Network Slice Selection Function
PCF: Policy Control Function
RAN: Radio Access Network
SMF: Session Management Function
UDM: Unified Data Management
UPF: User Plane Function

5G REPRESENTACIÓN DE PUNTOS DE REFERENCIA, HOME ROUTING



AF: Application Function
AMF: Access and Mobility Management Function
AUSF: Authentication Server Function
NSSF: Network Slice Selection Function
PCF: Policy Control Function
RAN: Radio Access Network
SMF: Session Management Function
UDM: Unified Data Management
UPF: User Plane Function

5G REPRESENTACIÓN DE PUNTOS DE REFERENCIA, LOCAL BREAKOUT



Discutir casos de uso de HR y LB

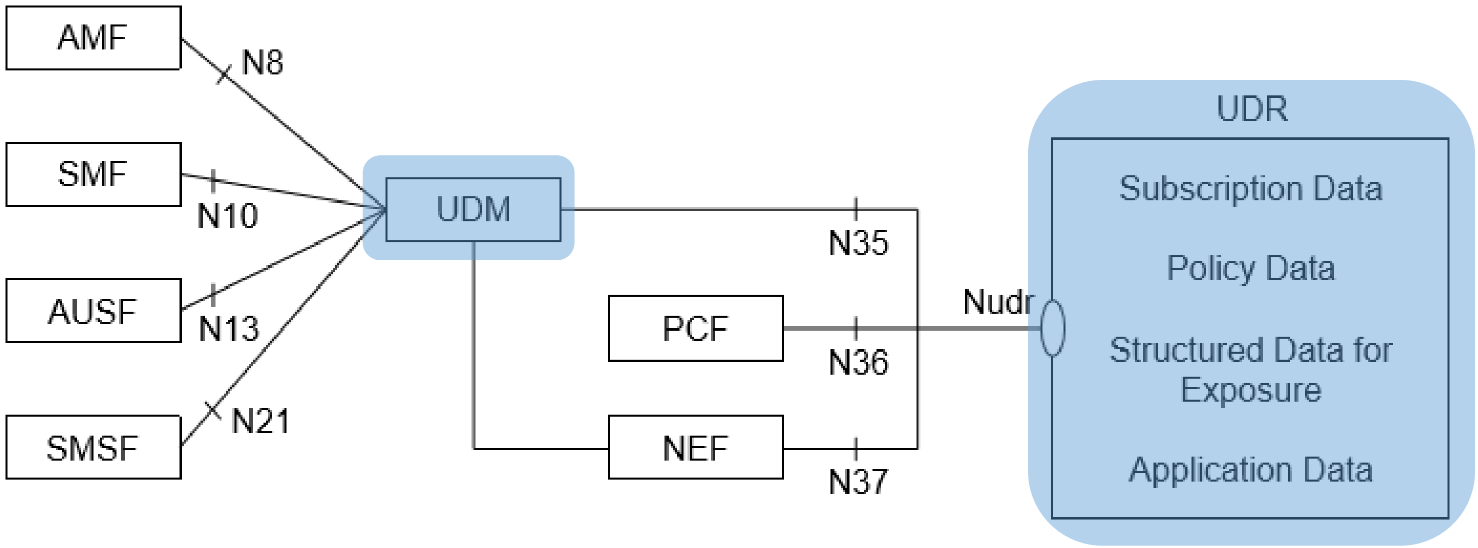
PUNTOS DE REFERENCIA

N1	UE – AMF
N2	(R)AN – AMF
N3	(R)AN – UPF
N4	SMF – UPF
N5	PCF – AF
N6	UPF – DN
N7	SMF – PCF
N8	UDM – AMF
N9	UPF – UPF
N10	UDM – SMF
N11	AMF – SMF
N12	AMF – AUSF
N13	UDM – AUSF
N14	AMF – AMF
N15	AMF – PCF
N16	SMF – SMF
N16a	*SMF – I-SMF*

N17	AMF – 5G-EIR
N18	Any NF – UDSF
N19	*Two PSA UPFs (5G-LAN)*
N20	AMF – SMSF
N21	UDM – SMSF
N22	AMF – NSSF
N23	PCF – NWDAF
N24	H-PCF – V-PCF
N25	PCF – UDR
N26	AMF – MME
N27	H-NRF – V-NRF
N28	PCF – CHF
N29	SMF – NEF
N29i	*I-NEF – SMF (in VPLMN)*
N30	PCF – NEF
N31	V-NSSF – H-NSSF
N32	V-SEPP – H-SEPP

N33	NEF – AF
N34	NSSF – NWDAF
N35	UDM – UDR
N36	PCF – UDR
N37	NEF – UDR
N38	*I-SMF – I-SMF*
N40	SMF – CHF
N50	AMF – CBCF
N51	*NEF – AMF*
N51i	*I-NEF – AMF (in VPLMN)*
N52	*NEF – UDM*
N52	*I-NEF – NEF*
N55	*AMF – UCMF*
N56	*NEF – UCMF*
N57	*AF -- UCMF*
N58	*AF – NEF*

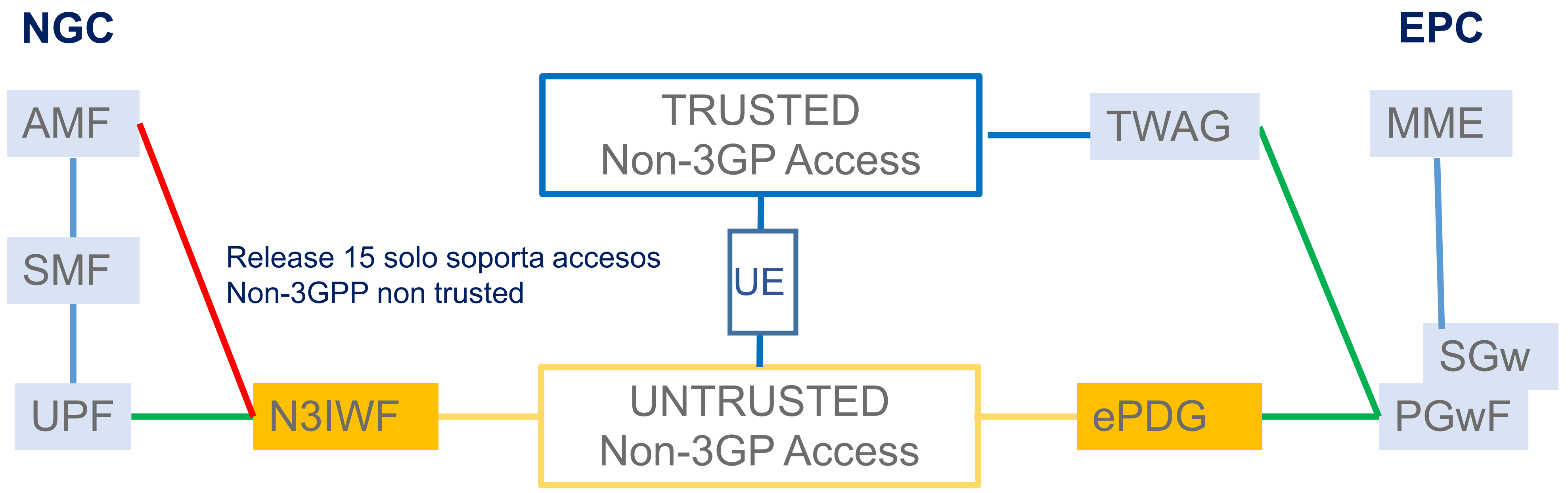
UDM AND UDR



AMF: Access and Mobility Management Function
AUSF: Authentication Server Function
IoT: Internet of Things
NEF: Network Exposure Function
PCF: Policy Control Function
SMF: Session Management Function
UDM: Unified Data Management
UDR: Unified Data Repository

A nivel de "provisioning" no existe una equivalencia directa entre EPC y NGC (5GC).
Se requiere un método de generación dinámica de subscripción y otro estática (la provisionada al momento de crear el suscriptor).
Una vez creado el suscriptor (UDR), el "suscription management" (UDM) es necesario. Ello puede ocurrir debido a múltiples causas como el cambio de titularidad de un dispositivo IOT, un update de credenciales, o simplemente como una medida de prevención

ACCESOS Non 3GPP EN 4G Y EN 5G



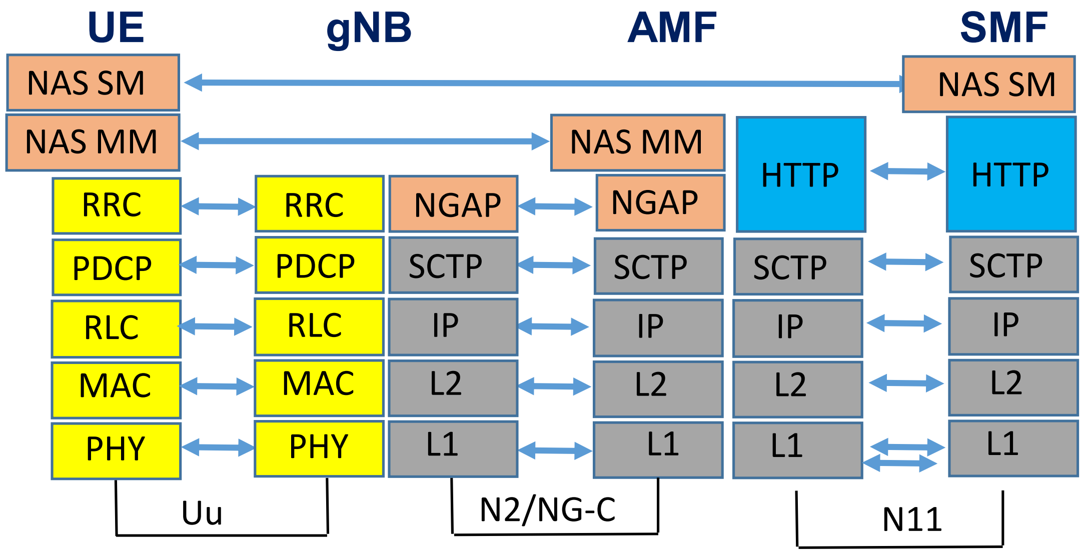
N3GPP TAI: Única Tracking Area
Para los accesos non-3GPP al 5GC

Los dispositivos sobre un acceso
Non-3GPP no pueden recibir paging
(tampoco SMS)

ePDG: evolved Packet Data Gateway
N3IWF: Non-3GPP InterWorking Function
TWAG: Trusted WLAN Access Gaeway

STACK DE PROTOCOLOS CON NG-RAN e INTERCONEXIÓN CON NGC

PLANO DE CONTROL (CP)



Nuevo!!!

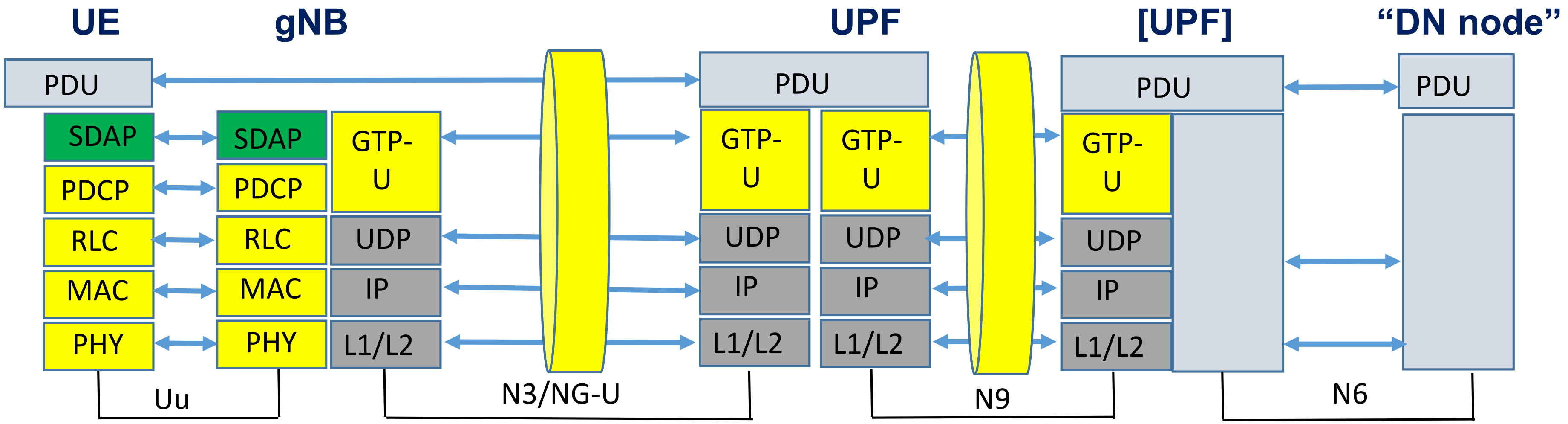
Nombre nuevo, reemplaza protocoo similar

No cambia el nombre, mejorado

El mismo que en LTE

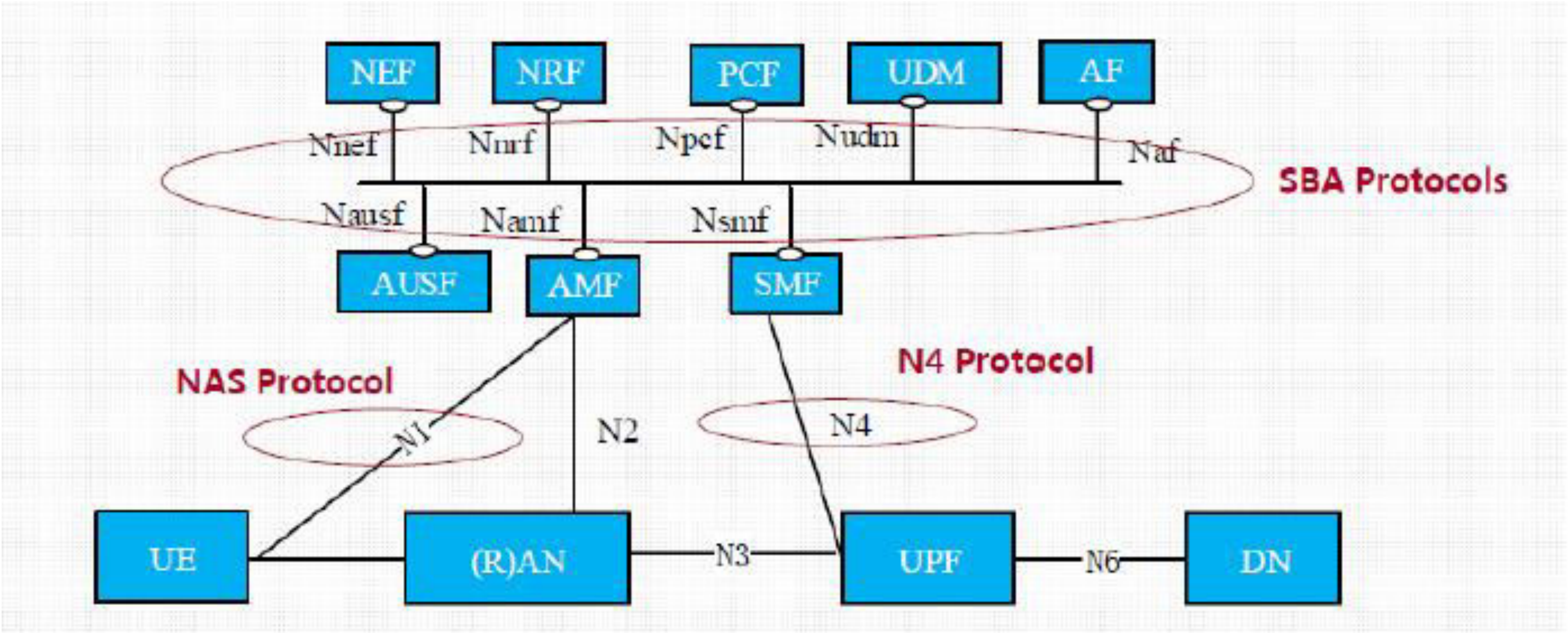
Protocolo viejo, pero nuevo para 3GPP

PLANO DE USUARIO (UP)



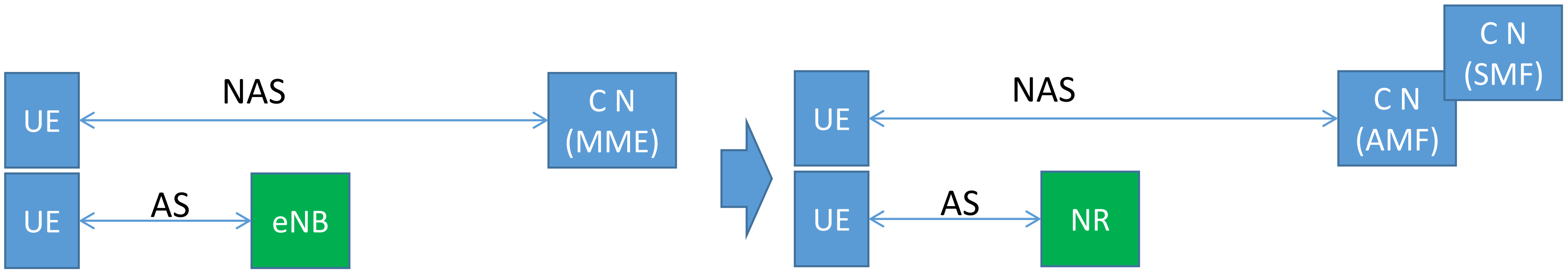
PROTOCOLOS DE CORE (GENERAL)

SBA architecture is moving to a Service Oriented Architecture (SOA) approach where control functions will communicate via HTTP 2.0 and APIs based on YAML (Yet another marking Languaje) and JSON (Java Script Object Notation).



PROTOCOLOS DE CORE (ENTRE UE Y AMF)

NAS PROTOCOLS: NAS handles the UE access to the network



NAS over EAP-5G

NAS over PPOE

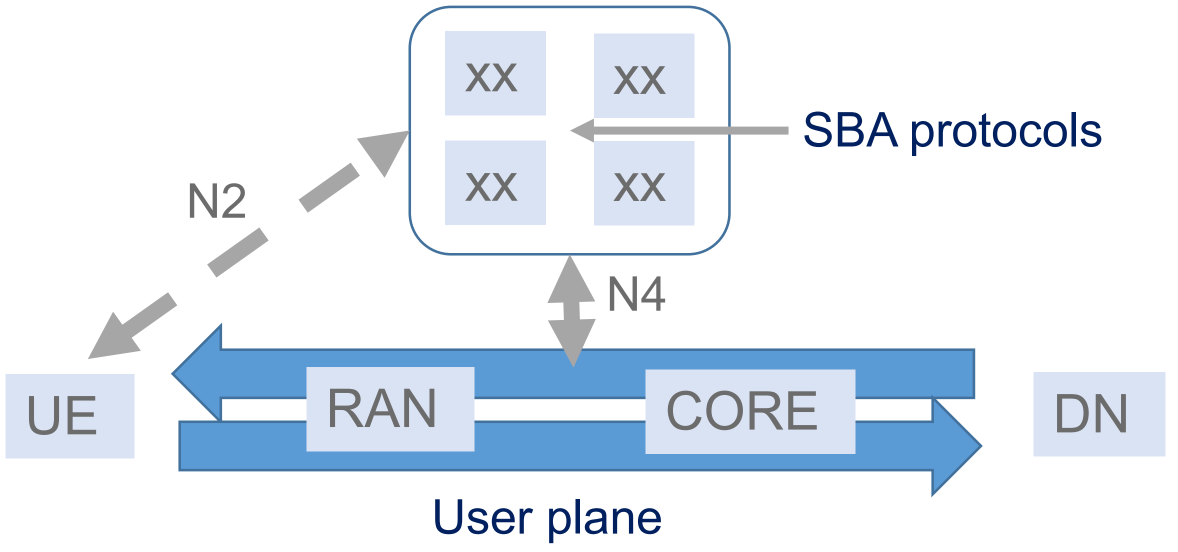
NAS over IP

PROTOCOLOS DE CORE (VERTICAL)

N4 protocols. N4 is the interface binding the control plane and user plane of the 5G packet gateway. 3GPP defines the usage of the **Packet Forwarding Control Protocol (PFCP)** for the communication between the control and user plane elements affected by CUPS (Control and User Plane Separation). In addition, it is planned to reuse PFCP, with some enhancements, in the interface N4. The user plane is done via extension of GTP U (over UDP).

PROTOCOLOS DE CORE (SBA)

El NGC, como se ha visto, es muy diferente al EPC
Se introducen nuevas entidades, aparecen nuevos roles, y muchos mas puntos de referencia.
Ello implica nuevos desafíos:



TTI &SBA protocols: ¿A qué contribuyen?

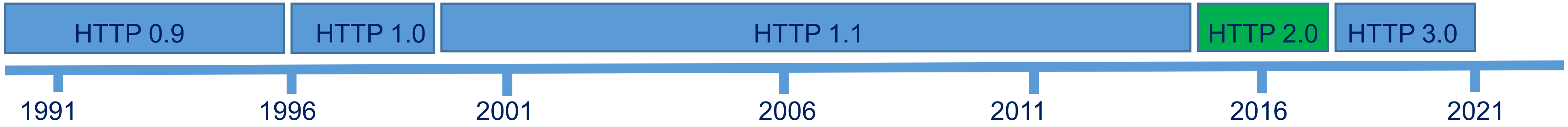
Pensar en algunas características de los protocolos de SBA

PROTOCOLOS DE CORE (SBA)

HTTP 2.0.

En SBA, a diferencia de las arquitecturas 3GPP de Core anteriores, basadas en Diameter y GTP, se introduce el uso de HTTP 2.0.

HTTP 2.0 no modifica la semántica de aplicación de HTTP. Todos los conceptos básicos, tales como los métodos (mensajes) HTTP, códigos de estado (que se insertan en las respuestas), URI, y campos de cabecera, se mantienen sin cambios.



HTTP 2.0 introduce innumerables mejoras como el uso de una única conexión (paraleliza conexiones TCP), la compresión de headers (reduce latencia), o el servicio ‘server push’.

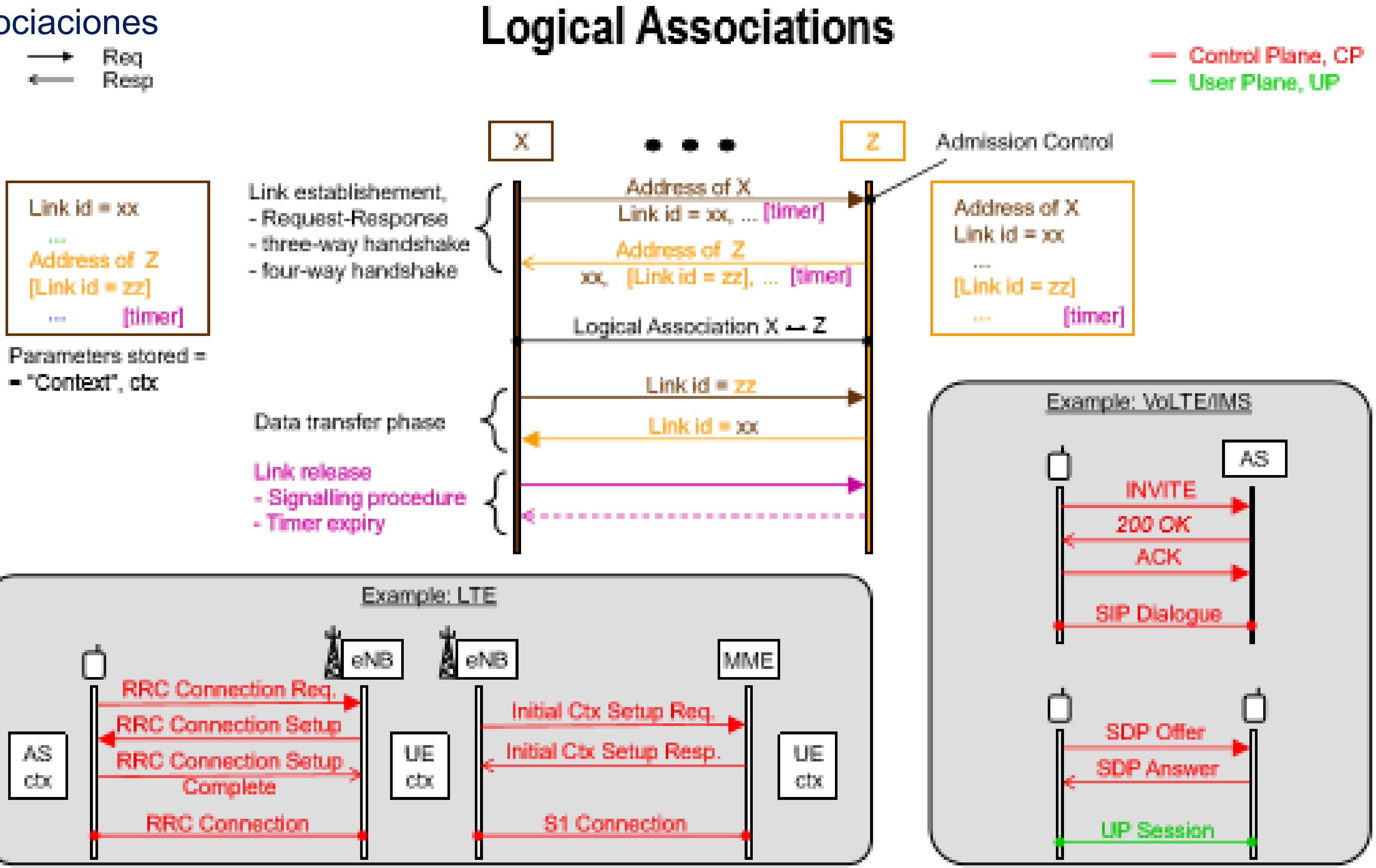
Aplicación	**HTTP/2**
Transporte	TCP
Red	IP

Es correcto este “stack” de protocolos?

SERVICE BASED ARCHITECTURE

Algunos ejemplos de asociaciones
Lógicas y Req-Resp

Req
Resp



SERVICE BASED ARCHITECTURE CARACTERÍSTICAS DE HTTP 2.0

Una sola conexión

HTTP/1.x exige el uso de múltiples conexiones TCP simultáneas para cargar cualquier contenido web, ya que es preciso descargar todos los elementos de dicha web. En cambio, con HTTP 2.0 se requiere una única conexión para ofrecer múltiples solicitudes y respuestas en paralelo.

Eliminación de información redundante

HTTP 2.0 elimina la información redundante, evitando el envío de datos repetidos durante una misma conexión.

Multiplexación

Con HTTP/1.1 el navegador envía una petición y debe esperar la respuesta del servidor para poder enviar la siguiente solicitud. Las webs actuales suelen tener centenas de objetos, lo que significa que, multiplexando se reduce el retardo.

La multiplexación permite enviar y recibir varios mensajes al mismo tiempo optimizando la comunicación. Con la multiplexación se consigue reducir el número de conexiones mejorando considerablemente la velocidad de carga y disminuyendo la congestión de los servidores web.

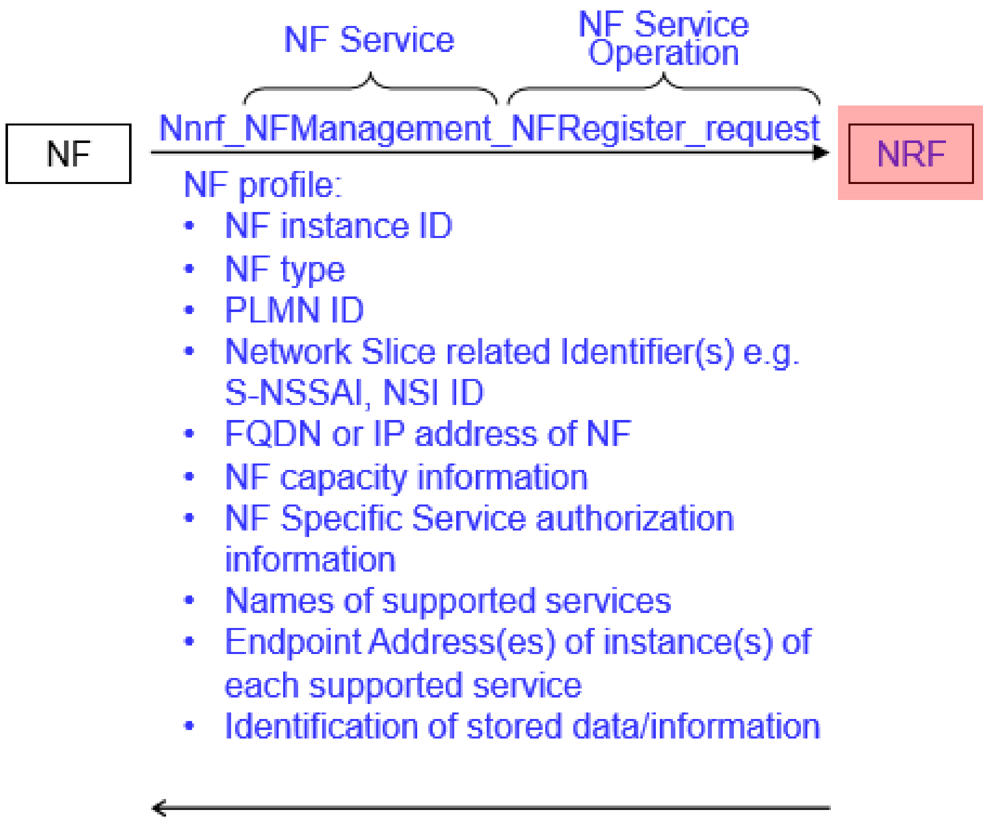
HTTP 2.0 es un protocolo binario

HTPP 1.x, SIP, MEGACO, son protocolos modo texto. Con el uso de un protocolo binario es mas simple determinar el comienzo y el final de cada trama, lo cual es realmente complicado en cualquier protocolo de texto. Además, los protocolos binarios son mucho más simples y por lo tanto son menos propensos a tener errores que los protocolos de texto utilizados por las versiones anteriores a HTTP 2.0.

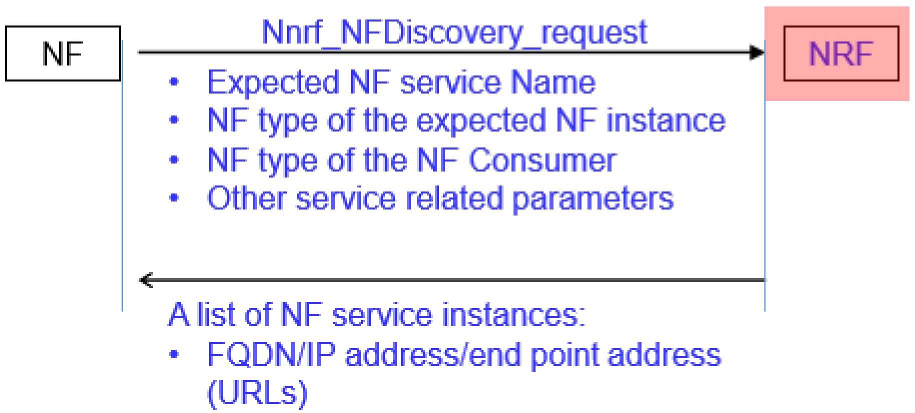
SERVICE BASED ARCHITECTURE

En la arquitectura SBA hay un nodo muy particular, el **NRF** (Network Repository Function).
La adopción de SBA en el CP implica un mecanismo de "discovery" y autorización, por el cual deben pasar todos los módulos para poder acceder a la red y hablar con otros.

Registración de NF en NRF

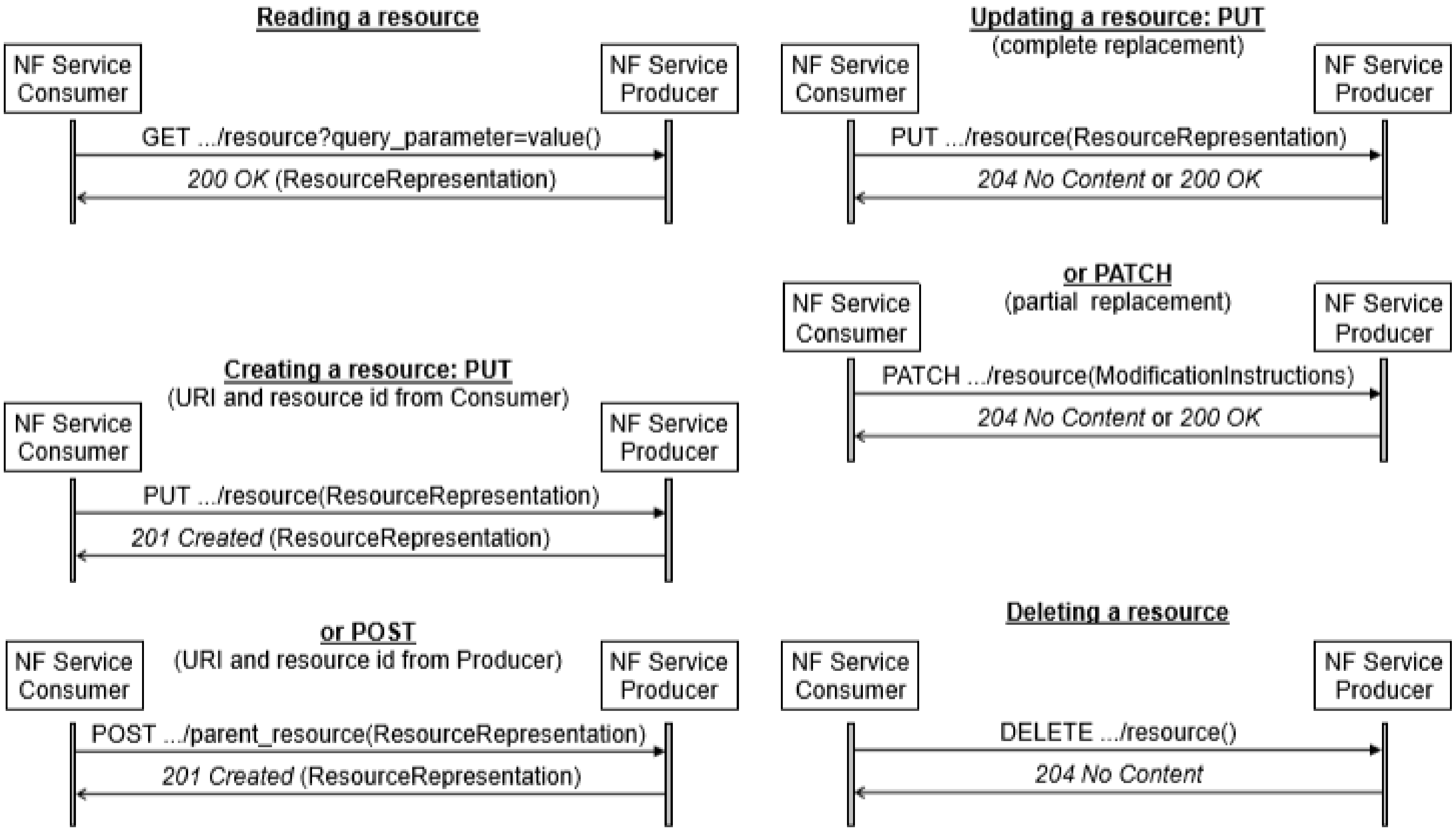


NF es descubierto por otro NF



NF: Network Function
NSI: Network Slice Instance
NSSAI: Network Slice Selection Assistance Information
FQDN: Fully Qualified Domain Network
PLMN: Public Land Mobile Network
S-NSSAI: Singe NSSAI
URL: Uniform Resource Locator

USO DE HTTP V2 EN SERVICE BASED ARCHITECTURE



Paradigma REST en diseño de APIs:

Create – POST
Read – GET
Update – PUT/PATCH
Delete – DELETE

HEADERS DE SOPORTE MANDATORIO EN REQUEST HTTP V2

En HTTP, lo mismo que en SIP, los métodos contienen headers (serían algo como parámetros)

Name	Reference	Description
Accept	IETF RFC 7231	This header is used to specify response media types that are acceptable.
Accept-Encoding	IETF RFC 7231	This header may be used to indicate what response content-encodings (e.g gzip) are acceptable in the response.
Content-Length	IETF RFC 7230	This header is used to provide the anticipated size, as a decimal number of octets, for a potential payload body.
Content-Type	IETF RFC 7231	This header is used to indicate the media type of the associated representation.
User-Agent	IETF RFC 7231	This header shall be mainly used to identify the NF type of the HTTP/2 client. The pattern of the content should start with the value of NF type (e.g. udm, see NOTE 1) and followed by a "-" and any other specific information if needed afterwards.
Cache-Control	IETF RFC 7234	This header may be used in some HTTP/2 requests to provide the HTTP cache-control directives that the client is willing to accept from the server.
If-Modified-Since	IETF RFC 7232	This header may be used in a conditional GET request, for server revalidation. This is used in conjunction with the Last-Modified server response header, to fetch content only if the content has been modified from the cached version.
If-None-Match	IETF RFC 7232	This header may be used in a conditional GET request. This is used in conjunction with the ETag server response header, to fetch content only if the tag value of the resource on the server differs from the tag value in the If-None-Match header.
If-Match	IETF RFC 7232	This header may be used in a conditional POST or PUT or DELETE or PATCH request. This is used in conjunction with the ETag server response header, to update / delete content only if the tag value of the resource on the server matches the tag value in the If-Match header.
Via	IETF RFC 7230	This header shall be inserted by HTTP proxies.
Authorization	IETF RFC 7235	This header shall be used if OAuth 2.0 based access authorization with "Client Credentials" grant type is used as specified in subclause 13.4.1 of 3GPP TS 33.501 [17], clause 7 of IETF RFC 6749 [22] and IETF RFC 6750.
NOTE 1: The value of NF type in the User-Agent header shall comply with the enumeration value of Table 6.1.6.3.3-1 in TS 29.510.		

HEADERS DE SOPORTE MANDATORIO EN RESPUESTAS HTTP V2

En HTTP, lo mismo que en SIP, los métodos contienen headers (serían algo como parámetros)

Name	Reference	Description
Content-Length	IETF RFC 7230	This header may be used to provide the anticipated size, as a decimal number of octets, for a potential payload body.
Content-Type	IETF RFC 7231	This header shall be used to indicate the media type of the associated representation.
Location	IETF RFC 7231	This header may be used in some responses to refer to a specific resource in relation to the response.
Retry-After	IETF RFC 7231	This header may be used in some responses to indicate how long the user agent ought to wait before making a follow-up request.
Content-Encoding	IETF RFC 7231	This header may be used in some responses to indicate to the HTTP/2 client the content encodings (e.g gzip) applied to the response body beyond those inherent in the media type.
Cache-Control	IETF RFC 7234	This header may be used in some responses (e.g. NRF responses to queries) to provide HTTP response cache control directives. The cache directives "no-cache", "no-store", "max-age" and "must-revalidate" values shall be supported.
Age	IETF RFC 7234	This header may be inserted by HTTP proxies when returning a cached response. It conveys the sender's estimate of the amount of time since the response was generated or successfully validated at the origin server. The presence of an Age header field implies that the response was not generated or validated by the origin server for this request.
Last-Modified	IETF RFC 7232	This header may be sent to allow for conditional GET with the If-Modified-Since header.
ETag	IETF RFC 7232	This header may be sent to allow for conditional GET with the If-If-None-Match header or a conditional POST / PUT / PATCH / DELETE with the If-Match header.
Via	IETF RFC 7230	This header shall be inserted by HTTP proxies.
Allow	IETF RFC 7231	This header field shall be used to indicate methods supported by the target resource.
WWW-Authenticate	IETF RFC 7235	This header field shall be included when an NF service producer rejects a request with a "401 Unauthorized" status code (e.g when a request is sent without an OAuth 2.0 access token or with an invalid OAuth 2.0 access token).

CÓDIGOS DE ESTADO DE SOPORTE MANDATORIO EN HTTP V2

"200 OK" response used on SBI shall contain body.

HTTP status code
100 Continue
200 OK
201 Created
202 Accepted
204 No Content
300 Multiple Choices
303 See Other
307 Temporary Redirect
308 Permanent Redirect
400 Bad Request
401 Unauthorized
403 Forbidden
404 Not Found
405 Method Not Allowed

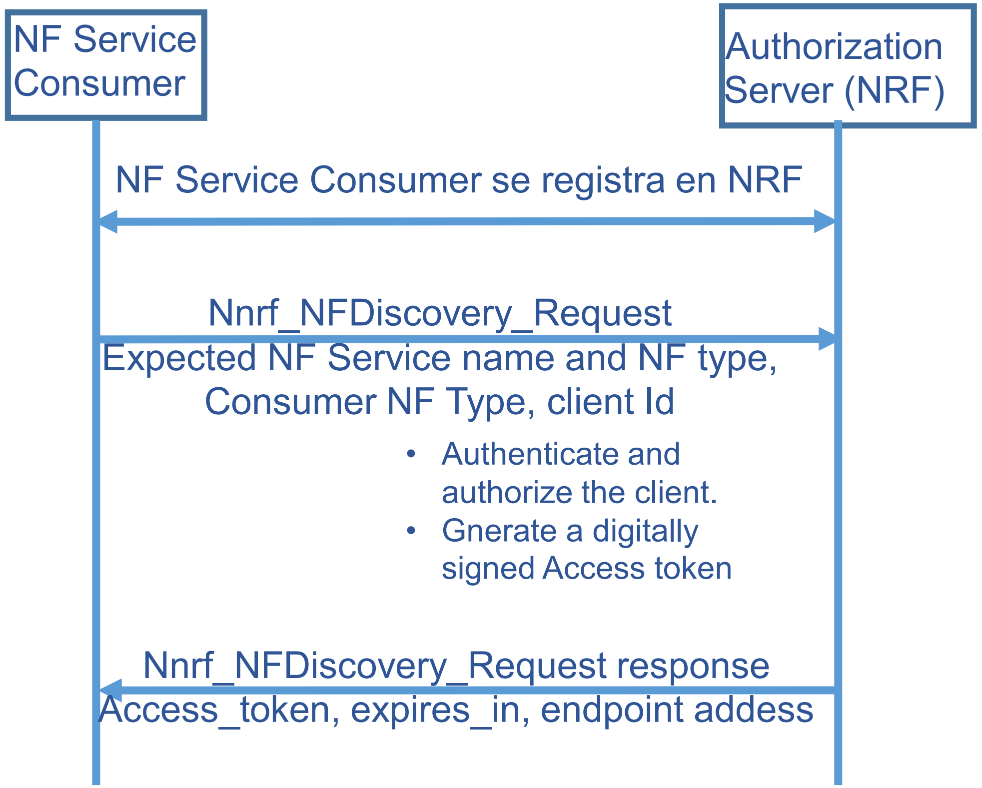
HTTP status code
406 Not Acceptable
408 Request Timeout
409 Conflict
410 Gone
411 Length Required
412 Precondition Failed
413 Payload Too Large
414 URI Too Long
415 Unsupported Media Type
500 Internal Server Error
501 Not Implemented
503 Service Unavailable
504 Gateway Timeout

Fuente TS. 29.500

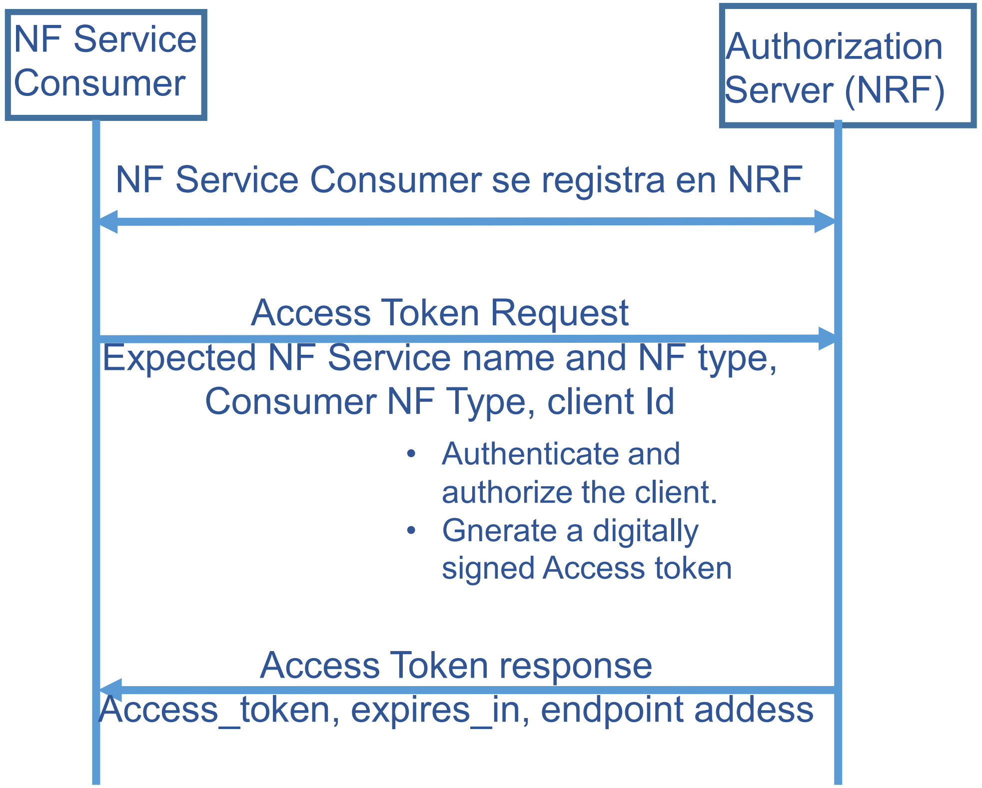
If the NF acting as an HTTP Client receives 2xx response code not from the table, the NF shall treat the received response:
- as "204 No Content" if 2xx response does not contain body; and
- as "200 OK" if 2xx response contains body.

AUTENTICACIÓN Y AUTORIZACIÓN DE UN NF SERVICE CONSUMER

Durante el “NF service discovery”



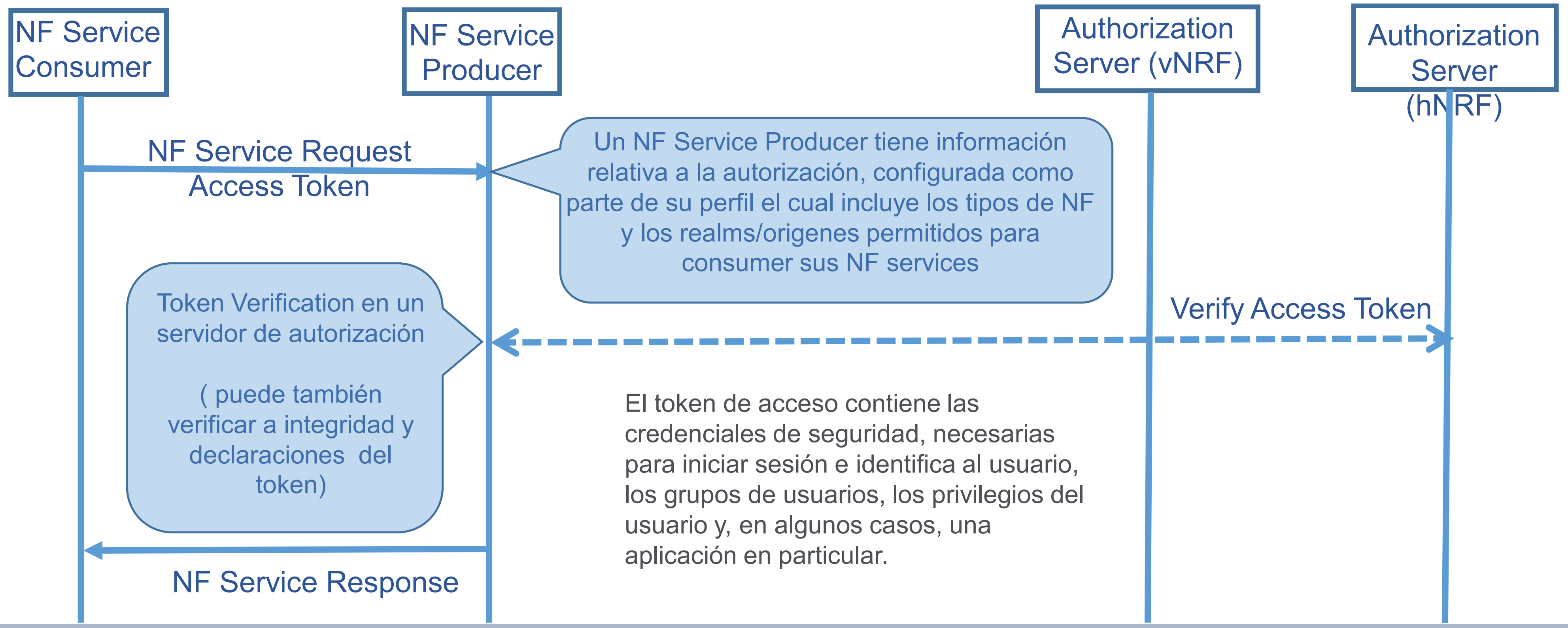
Antes del “NF service access”



NF SERVICE- MODELO DE CONSULTA Y RESPUESTA

En la arquitectura SBA cada vez que un NF, en su rol de consumidor (sería algo ánalogo a un cliente en Diameter), require un servicio de un un nodo Productor (analogo a un servidor en Diameter), debe ser autorizado antes de obterner la respuesta.

NF Service Consumer requiere acceso con access token



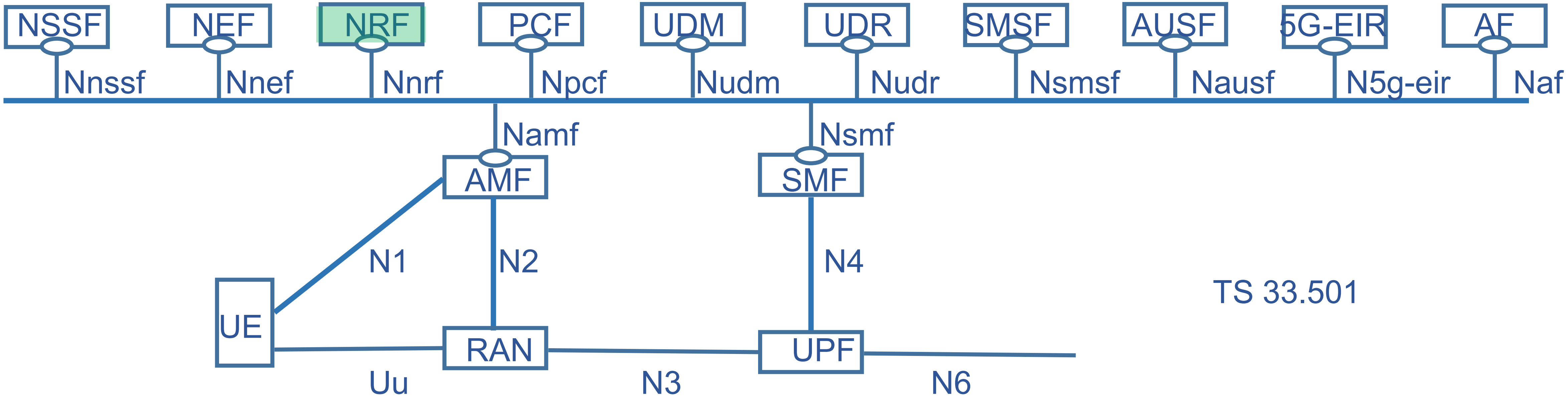
Proponer un ejemplo

ENTIDADES DEL NGC

AMF Access and Mobility Management Function. Which is an enhancement of the current MME able to perform dynamic selection of slicing and packet data gateway for use cases associated to MEC (mobile Edge Computing).
SMF. Session Management Function. The PGW is split in UPF (user plane) and SMF (control plane). SMF will be able to perform dynamic UPF selection for supporting the MEC concept.
NRF Network Repository Function. By adopting a service oriented architecture new discovery and authorization capability is required for the different module to access each other.
AUSF Authentication Server Function. New authentication functions used in order to support non SIM based devices.
NEF: Network Exposure Function.
NSSF. Network selection slicing function. Required in order to enhanced slice selection
UDM Unified Data Management. Stores subscriber data and profiles. Similar to an HSS in 4G, but will be used for both fixed and mobile access in 5G Core.
PCF Policy Control function. Provides a policy framework incorporating network slicing, roaming and mobility management. Equivalent to PCRF in 4G
UPF：User plane Function.
DN：Data network.
SDSF: Structured Data Storage Network Function .
UDSF: Unstructured Data Storage network function.
UDM：Unified Data Management.
AF： Application Function.

SERVICIOS PROPORCIONADOS POR EL **NRF**

Service Name	Description
Nnrf_NFManagement	Provides support for register, deregister and update service to NF, NF services. Provide consumers with notifications of newly registered NF along with its NF services.
Nnrf_NFDiscovery	Enables one NF service consumer to discover a set of NF instances with specific NF service or a target NF type. Also enables one NF service to discover a specific NF service.
Nnrf_AccessToken	Provides OAuth2 2.0 Access Tokens for NF to NF authorization as defined in TS 33.501

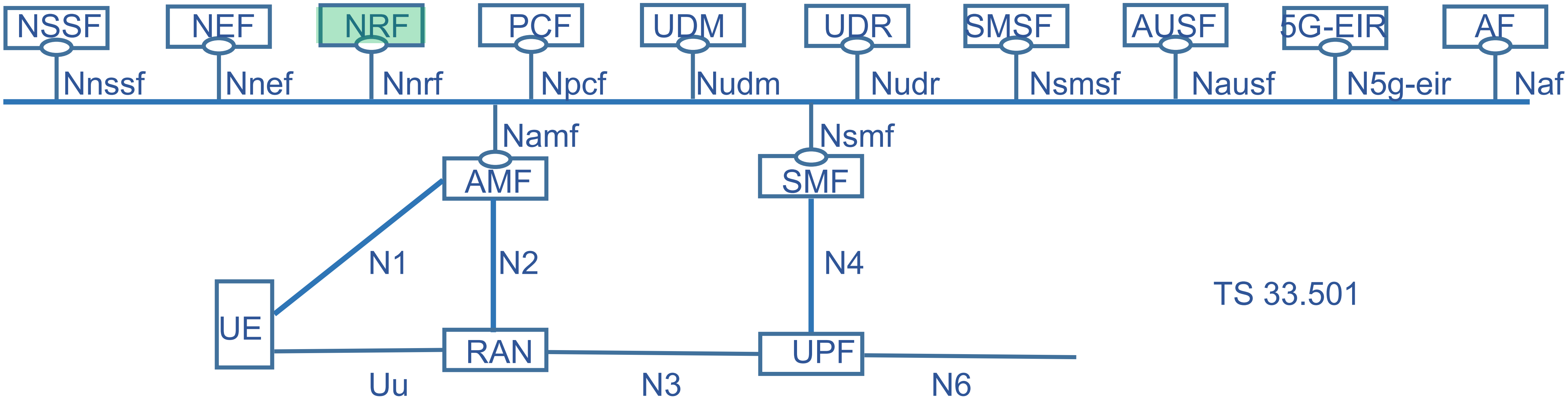


TS 33.501

SERVICIOS PROPORCIONADOS POR EL **NRF**

El NFR es un NF(función de red) definido por 3GPP 5G. Es una entidad del NGC que admite la interconexión entre NFs. Realiza funciones de gestión para monitorear el estado del servicio y la información de interfuncionamiento de NFs las que cambian dinámicamente.
Para la gestión de NF, el NRF proporciona las siguientes funciones de procesamiento de servicios a través de la SBI Nnrf (Service-Based-Interface) exhibidos por NRF, basada en HTTP2.

- Registro de servicio NF: administra la información del servicio 5G proporcionada por la instancia NF.
- NF Service Discovery: proporciona información de instancia NF que admite la SBI 5G.
- Token de acceso: proporciona tokens de autenticación y autorización para el uso de los servicios 5G Core.



TS 33.501

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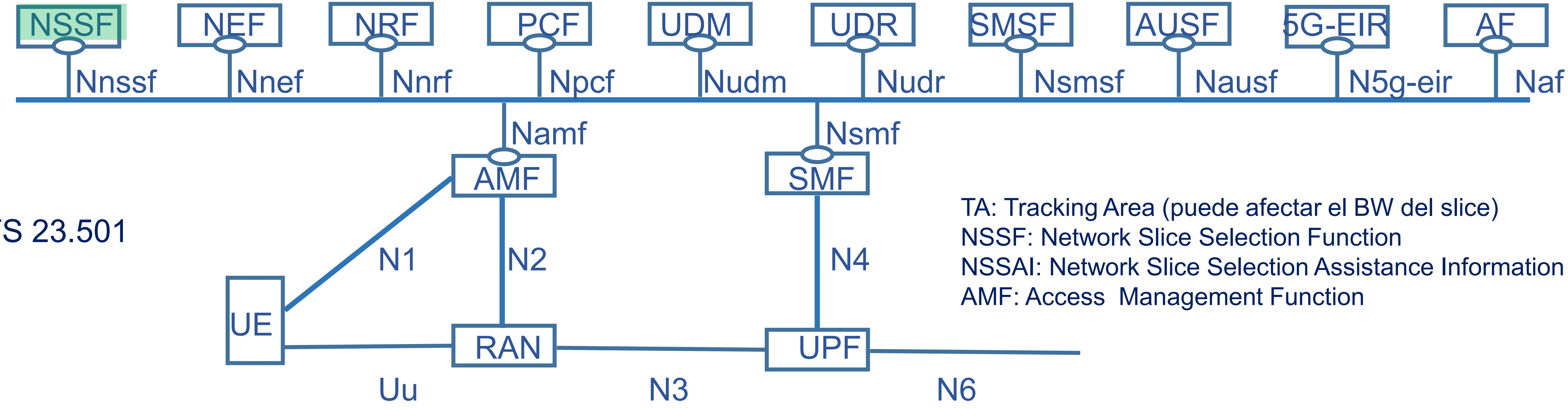
SERVICE PROPORCIONADOS POR EL **NSSF**

Service Name	Description
Nnssf_NSSelection	Provides the requested Network Slice information to the Requester.
Nnssf_NSSAIAvailability	Enables to update the AMFs and the NSSF on the availability of S-NSSAIs on a per TA basis.

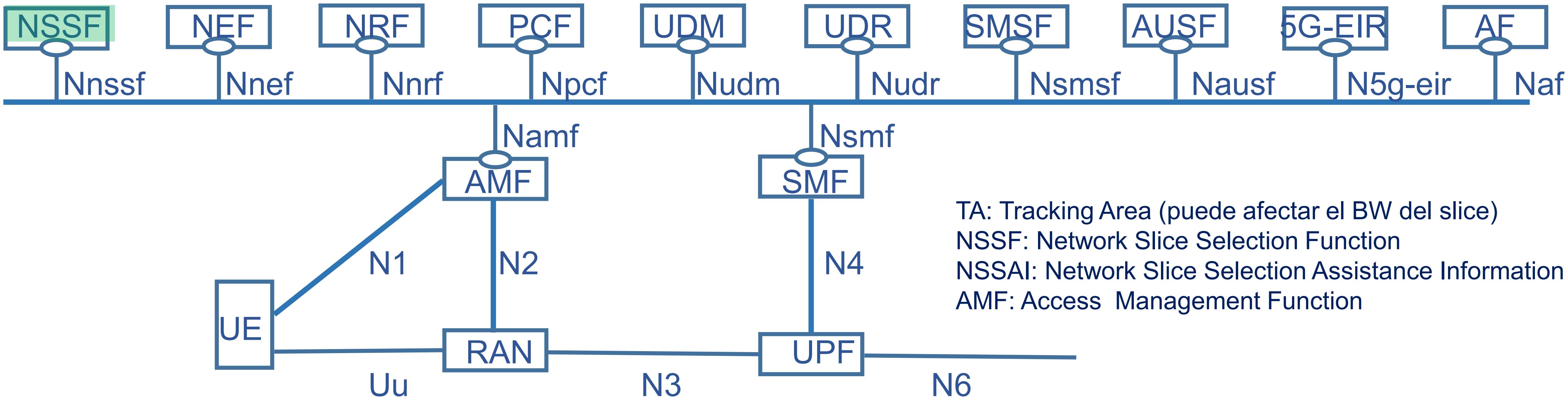


TS 23.501

TA: Tracking Area (puede afectar el BW del slice)
NSSF: Network Slice Selection Function
NSSAI: Network Slice Selection Assistance Information
AMF: Access Management Function

SERVICE PROPORCIONADOS POR EL **NSSF**

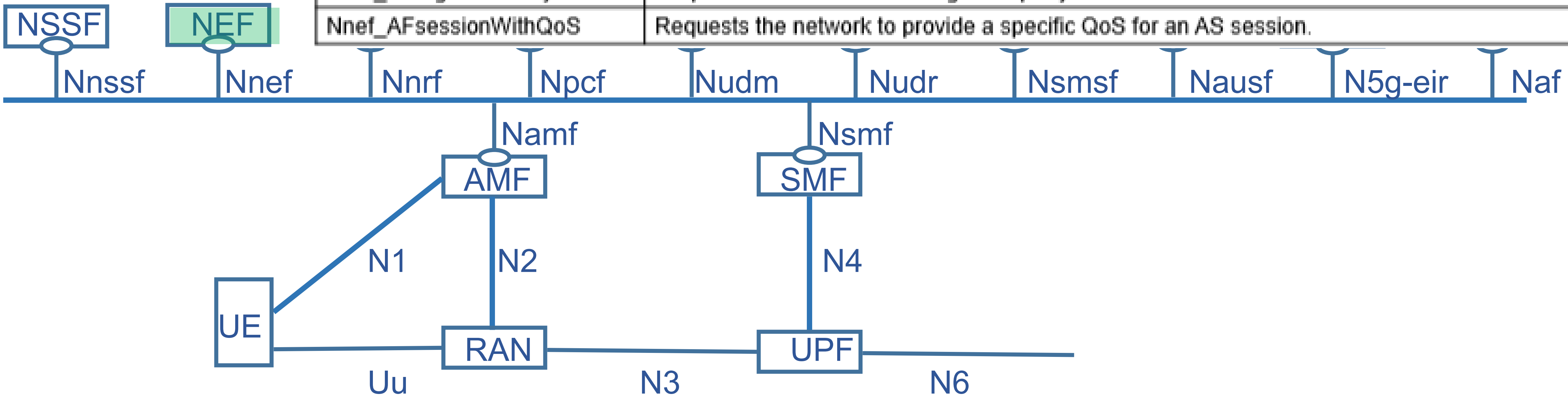
El sistema NSSF (Network Slicing Selection Function) permite seleccionar el segmento de red óptimo disponible para el servicio solicitado por el Usuario, en una red 5G donde se brindan varios servicios. También proporciona el AMF óptimo, o un set de información de AMF para respaldar el servicio solicitado autorizado para el usuario en la red.



TA: Tracking Area (puede afectar el BW del slice)
NSSF: Network Slice Selection Function
NSSAI: Network Slice Selection Assistance Information
AMF: Access Management Function

SERVICE PROPORCIONADOS POR EL **NEF**

Service Name	Description
Nnef_EventExposure	Provides support for event exposure
Nnef_PFDManagement	Provides support for PFDs management
Nnef_ParameterProvision	Provides support to provision information which can be used for the UE in 5GS
Nnef_Trigger	Provides support for device triggering
Nnef_BDTPNegotiation	Provides support for negotiation about the transfer policies for the future background data transfer
Nnef_TrafficInfluence	Provide the ability to influence traffic routing.
Nnef_ChargeableParty	Requests to become the chargeable party for a data session for a UE.
Nnef_AFsessionWithQoS	Requests the network to provide a specific QoS for an AS session.

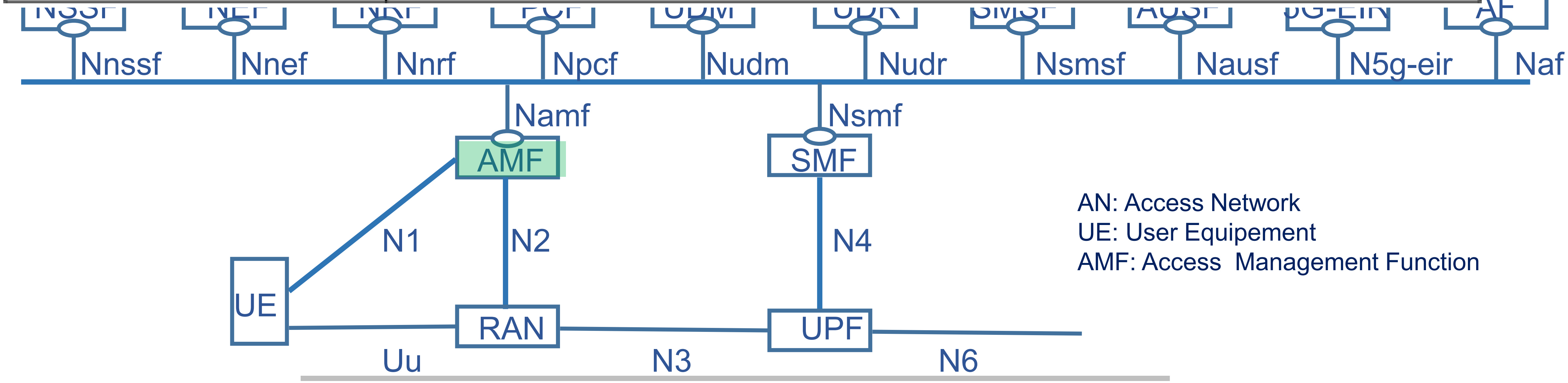


SERVICE PROPORCIONADOS POR EL **NEF**

- EL NEF (Network Exposure Function), permite hacer que el Core 5G sea programable a través de APIs.
- NEF permite crear nuevos servicios mediante el uso de API.
- Ofrece la presentación de acceso unificado al marco de API tanto para desarrolladores propios como para desarrolladores externos.
- Exposición segura de servicios de red (voz, conectividad de datos, carga, datos de suscriptores, etc.) hacia aplicaciones de terceros a través de API.
- Entorno de desarrollo y SDK para operador y comunidad
- Service Mashup para crear una oferta de extremo a extremo mediante la combinación de cualquiera de los activos de red.
- Capa de integración que conecta la aplicación a la red del operador.
- El marco de API se realiza a través de un concepto de plug-in, lo cual hace posible crear servicios complejos basados en APIs.
- Es posible agregar APIs adicionales con el tiempo, según las necesidades.
- Para operadores con Cores de múltiples proveedores, la función de exposición de red de algunos vendors (NOKIA p ej), puede exponer las API de las funciones de red de otros proveedores, lo cual es posible a través del uso de complementos de terceros.

SERVICE PROPORCIONADOS POR EL **AMF**

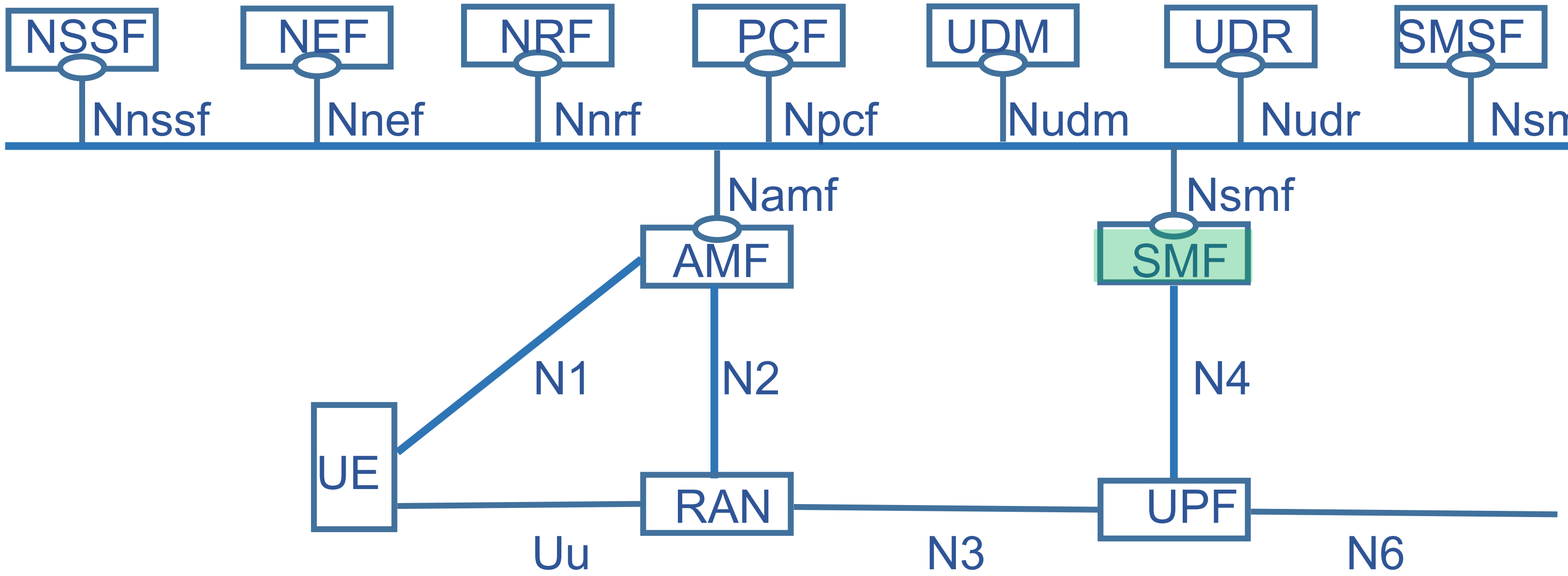
Service Name	Description
Namf_Communication	This service enables an NF to communicate with the UE and/or the AN through the AMF.
Namf_EventExposure	This service enables other NFs to subscribe or get notified of UE mobility related events and statistics.
Namf_MT	This service enables an NF to make sure UE is reachable.
Namf_Location	This service enables an NF to request location information for a target UE.



AN: Access Network
UE: User Equipement
AMF: Access Management Function

SERVICE PROPORCIONADOS POR EL **SMF**

Service Name	Description
Nsmf_PDUSession	Manages the PDU Sessions and uses the policy and charging rules received from the PCF. The service operations exposed by this NF service allows the consumer NFs to handle the PDU Sessions.
Nsmf_EventExposure	Exposes the events happening on the PDU Sessions to the consumer NFs.

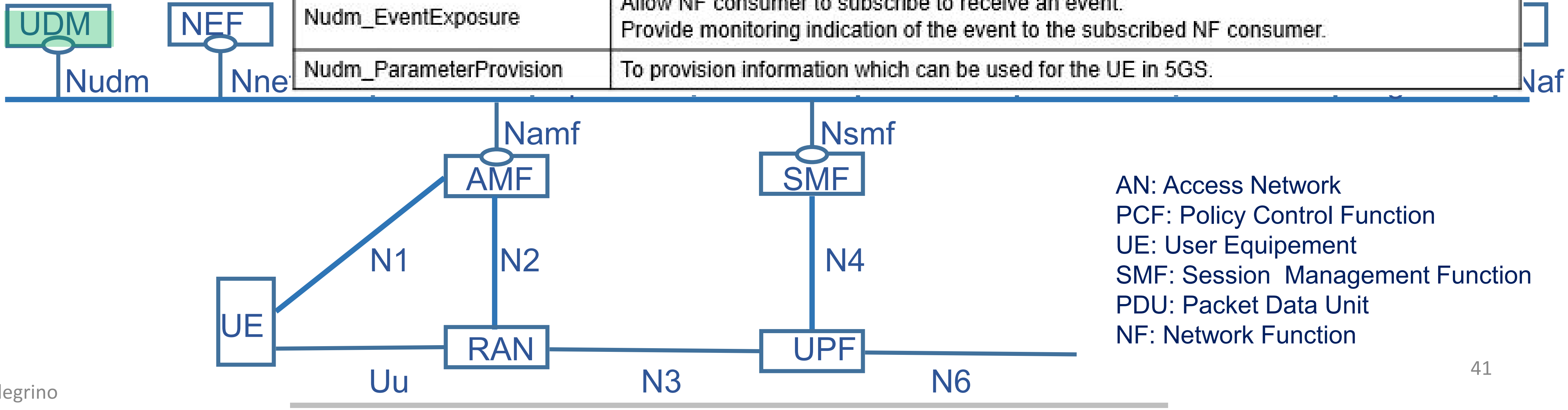


AN: Access Network
PCF: Policy Control Function
UE: User Equipement
SMF: Session Management Function
PDU: Packet Data Unit
NF: Network Function

Observar comunicación ente PCF y UPF en NGC. Comparar con PCRF y PGw en EPC

SERVICE PROPORCIONADOS POR EL **UDM**

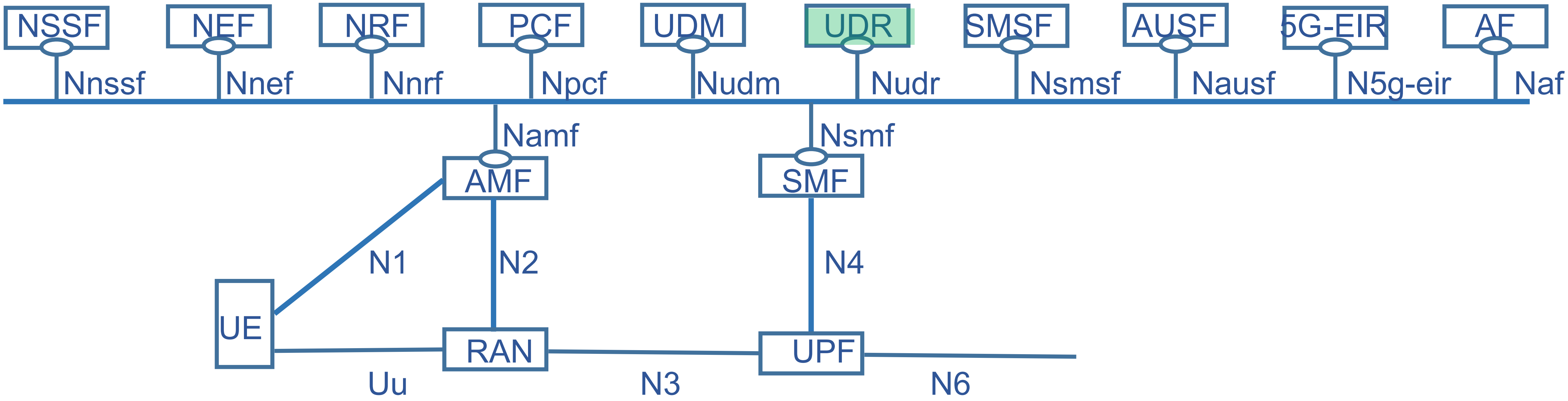
Service Name	Description
Nudm_UECM	Provide the NF consumer of the information related to UE's transaction information, e.g. UE's serving NF identifier, UE status, etc. Allow the NF consumer to register and deregister its information for the serving UE in the UDM. Allow the NF consumer to update some UE context information in the UDM.
Nudm_SDM	Allow NF consumer to retrieve user subscription data when necessary Provide updated user subscriber data to the subscribed NF consumer;
Nudm_UEAuthentication	Provide updated authentication related subscriber data to the subscribed NF consumer. For AKA based authentication, this operation can be also used to recover from security context synchronization failure situations. Used for being informed about the result of an authentication procedure with a UE.
Nudm_EventExposure	Allow NF consumer to subscribe to receive an event. Provide monitoring indication of the event to the subscribed NF consumer.
Nudm_ParameterProvision	To provision information which can be used for the UE in 5GS.



AN: Access Network
PCF: Policy Control Function
UE: User Equipement
SMF: Session Management Function
PDU: Packet Data Unit
NF: Network Function

SERVICE PROPORCIONADOS POR EL **UDR**

Service Name	Description
Nudr_DM	Allows NF consumers to retrieve, create, update, subscribe for change notifications, unsubscribe for change notifications and delete data stored in the UDR, based on the set of data applicable to the consumer. This service may also be used to manage operator specific data.



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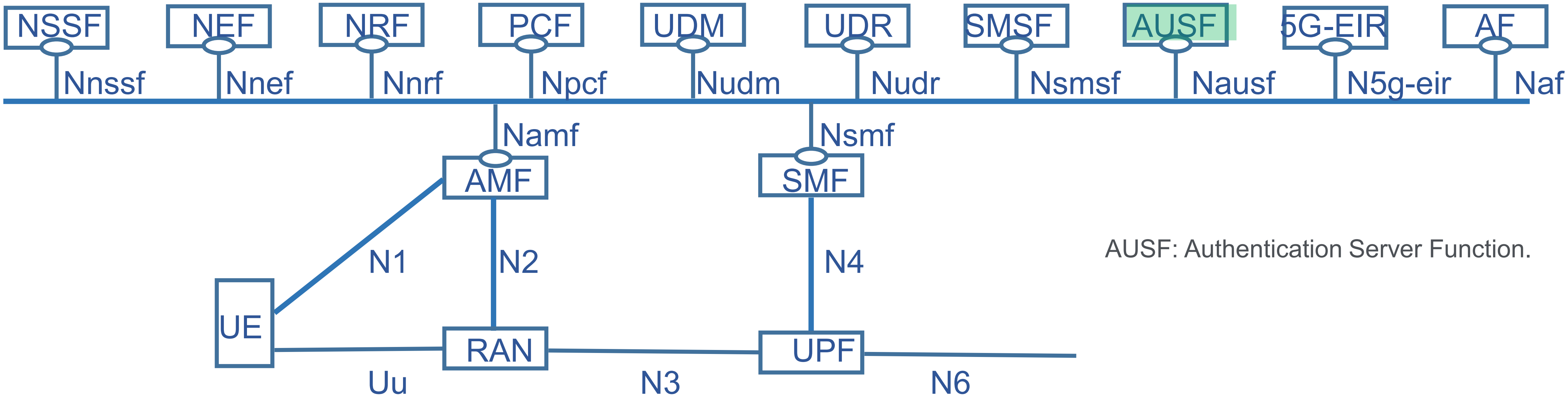
SERVICE PROPORCIONADOS POR EL **AUSF**

Service Name	Description
Nausf UEauthentication	The AUSF provides UE authentication service to requester NF. For AKA based authentication, this operation can also be used to recover from security context synchronization failure situations.
Nausf_SoRProtection	The AUSF provides protection of Steering of Roaming information service to the requester NF.

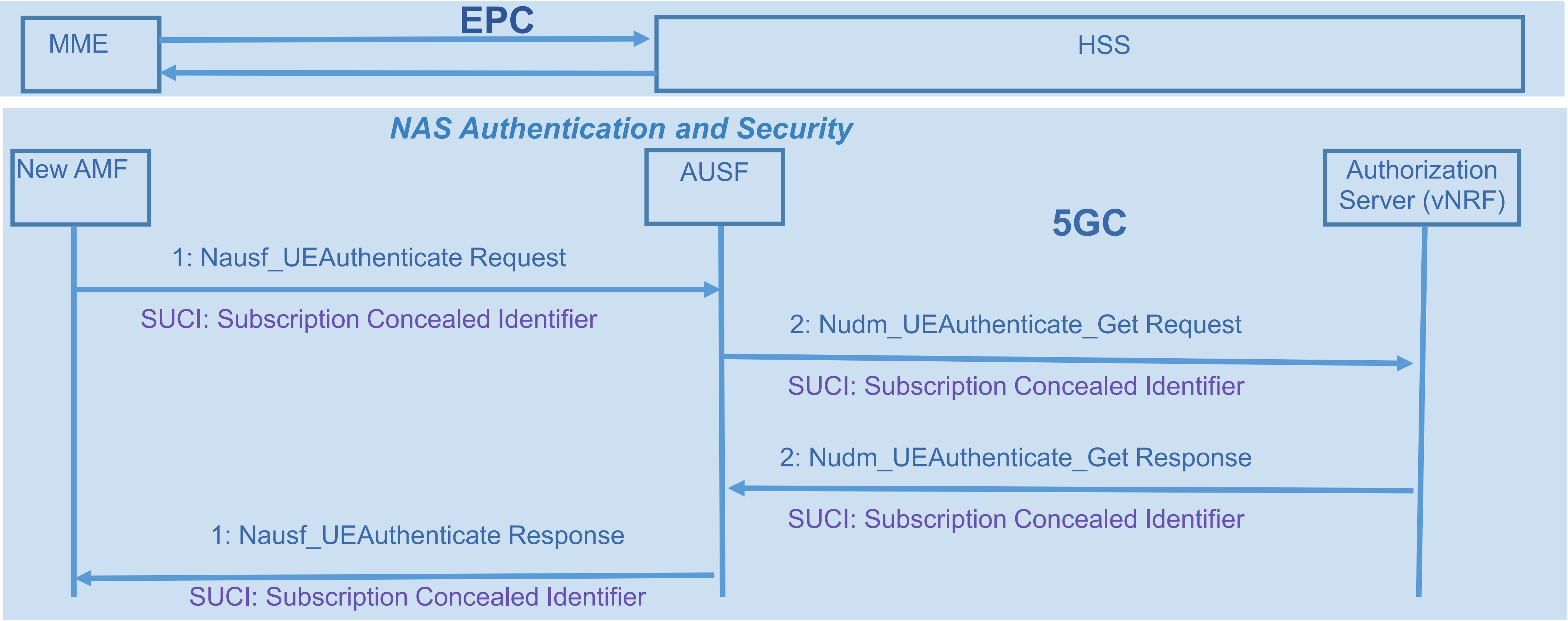


AUSF: Authentication Server Function.

SERVICE PROPORCIONADOS POR EL **AUSF**

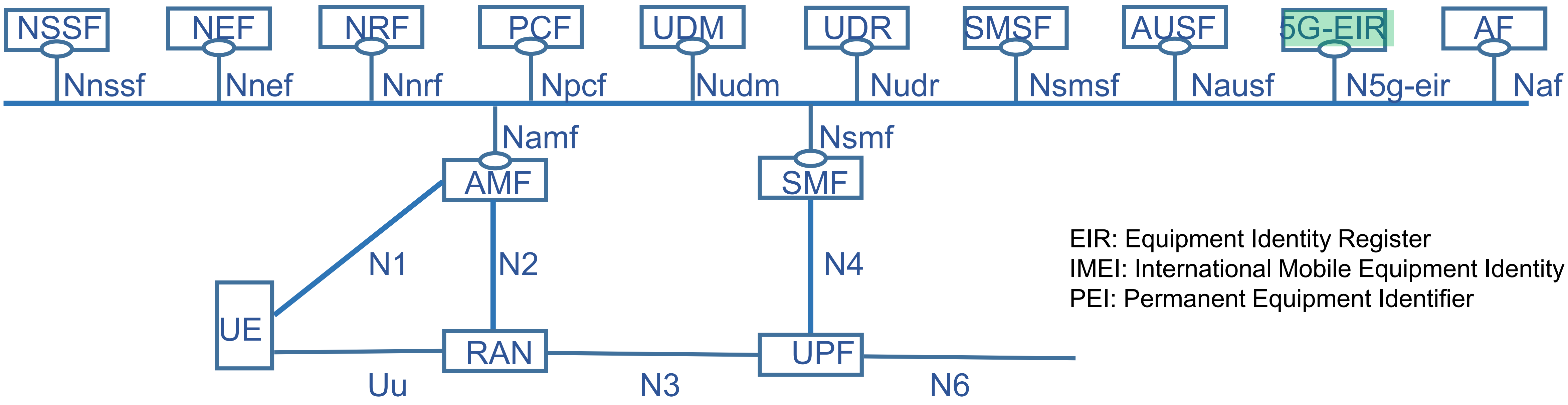
AUSF — Authentication Server Function
The AUSF performs the authentication function of 4G HSS.
•Implements the EAP authentication server
•Stores keys
AUSF role in 5G standalone registration.

https://medium.com/5g-nr/5g-service-based-architecture-sba-47900b0ded0a



SERVICE PROPORCIONADOS POR EL **5G-EIR**

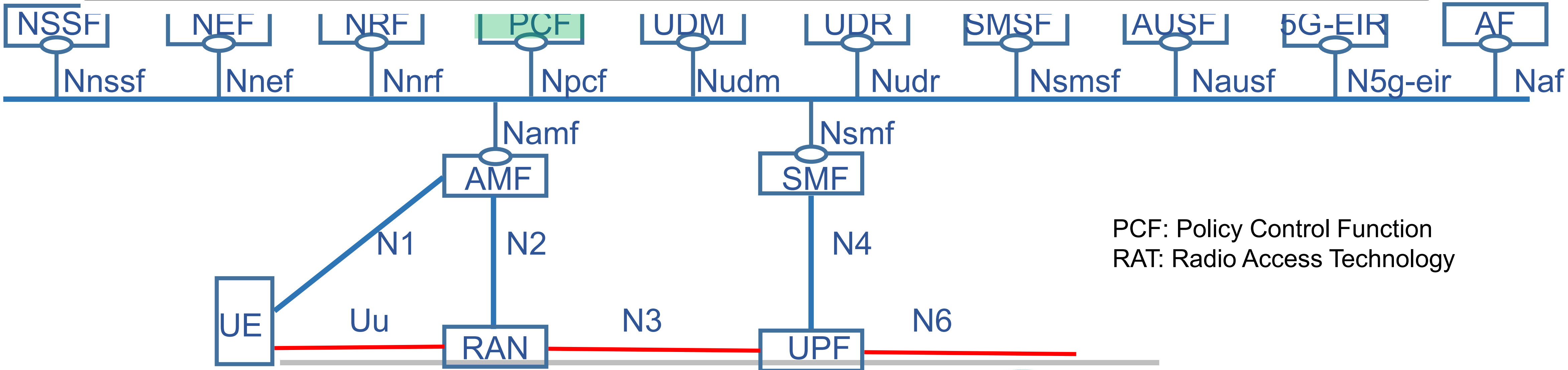
Service Name	Description
N5g-eir_Equipment Identity Check	This service enables the 5G-EIR to check the PEI and check whether the PEI is in the black list or not.



EIR: Equipment Identity Register
IMEI: International Mobile Equipment Identity
PEI: Permanent Equipment Identifier

SERVICE PROPORCIONADOS POR EL **PCF**

Service Name	Description
Npcf_AMPolicyControl	This PCF service provides Access Control, network selection and Mobility Management related policies, UE Route Selection Policies to the NF consumers.
Npcf_SMPolicyControl	This PCF service provides session related policies to the NF consumers.
Npcf_PolicyAuthorization	This PCF service authorises an AF request and creates policies as requested by the authorised AF for the PDU Session to which the AF session is bound to. This service allows the NF consumer to subscribe/unsubscribe to the notification of Access Type and RAT type, PLMN identifier, access network information, usage report etc.
Npcf_BDTPolicyControl	This PCF service provides background data transfer policy to the NF consumers.
Npcf_UEPolicyControl	This PCF service provides the management of UE Policy Association to the NF consumers.
Npcf_EventExposure	This PCF service provide the support for event exposure.

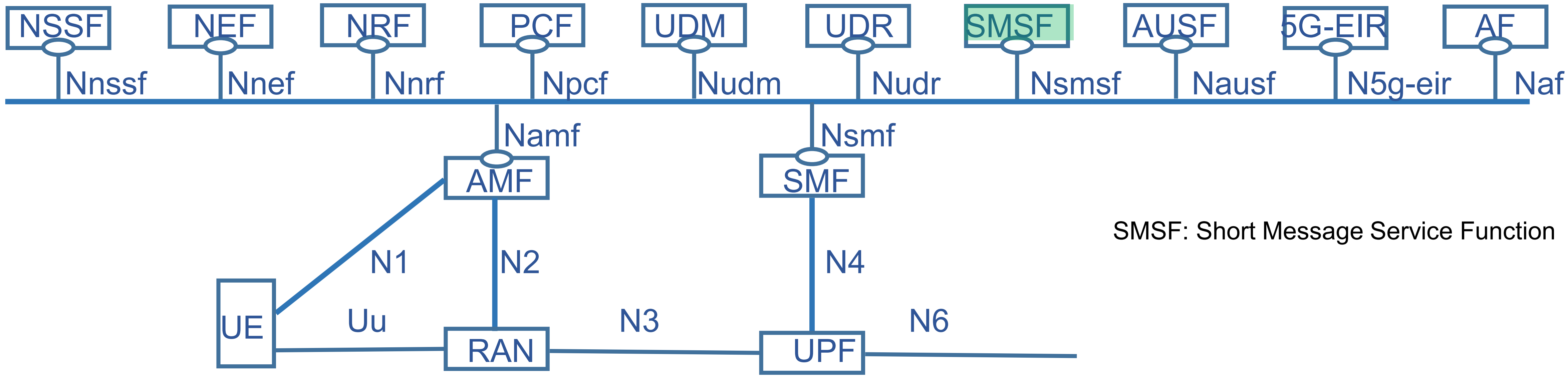


PCF: Policy Control Function
RAT: Radio Access Technology

SERVICE PROPORCIONADOS POR EL **SMSF**

Service Name	Description
Nsmsf_SMService	This service allows AMF: • to authorize SMS and activate SMS for the served user on SMSF, and • to transmit uplink SMS message from consumer NF to SMSF.

SMSF se usa para ofrecer SMS sobre NAS a través del AMF.
Es algo análogo al IP-SM-Gw de EPC
El SMSF se comunica con SMSC de la Red legada a través de la interfaz SGd



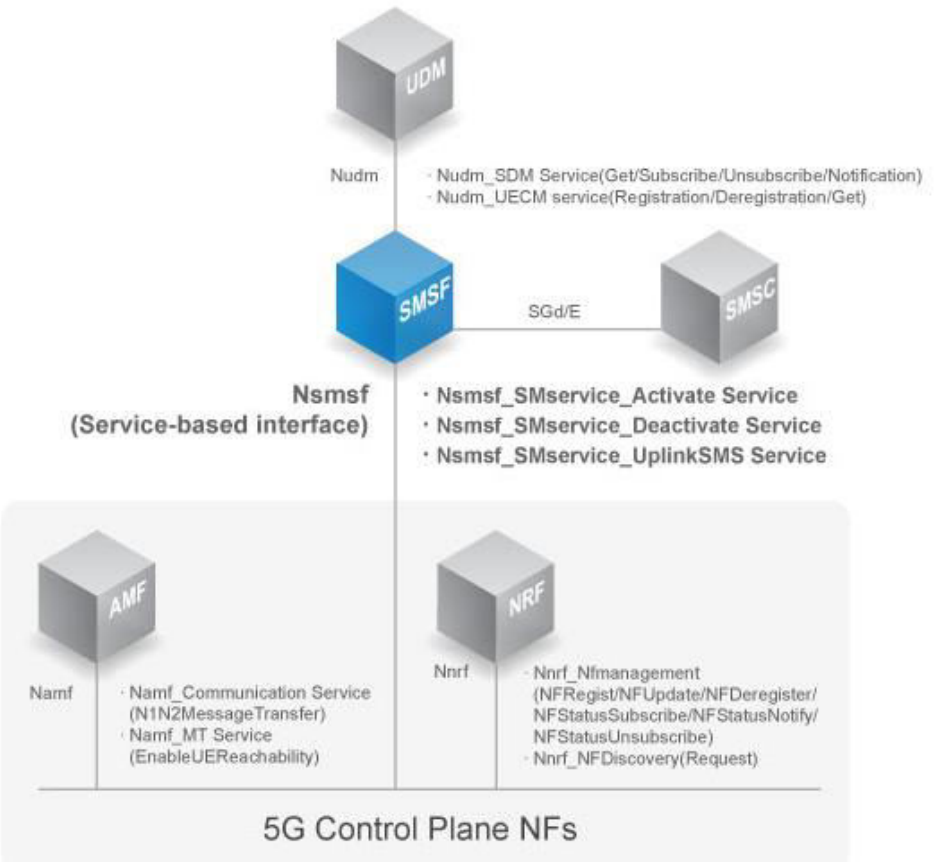
SMSF: Short Message Service Function

SERVICE PROPORCIONADOS POR EL SMSF

Service Name	Description
Nsmsf_SMService	This service allows AMF: • to authorize SMS and activate SMS for the served user on SMSF, and • to transmit uplink SMS message from consumer NF to SMSF.

http://www.telcoware.com/eng_191127/01_product/0904_smsf.asp

http://www.telcoware.com/eng_191127/01_product/0903_5geir.asp



NETWORK SLICING

slice management functions

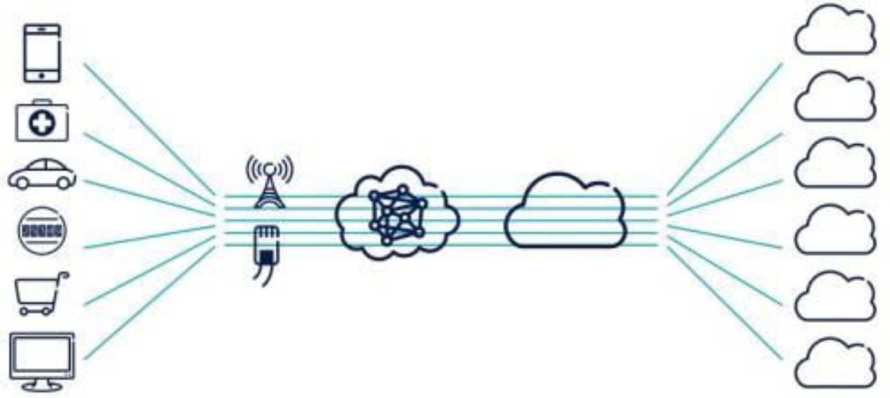
Full automation of network slice management, NFV Management & Orchestration functions (NFV-MANO) need to be complemented and interwork with slice management functions.

Operation Support System

Slice management could be regarded as a particular Operations Support System (OSS) functional area which needs to be standardized on top of NFV. This includes specifying a mechanism for mapping network slice requirements onto Network Services capabilities.

Network slice as a logical network

According to 3GPP, a Network slice is a logical network serving a defined business purpose or customer, consisting of all required network resources configured together.



NETWORK SLICING

La primera clasificación que surge al considerer un mecanismo que ofrezca una porción de la red de acuerdo al tipo de servicio (eso es en esencia el Network Slicing), es pensar justamente en las tres categorías de servicios:
eMBB (Enhanced Mobie Bradband), URLLC (Ultra-Reliable Low Latency Communication), y mMTC (Massive Machine Type Communication)

SST = 1, eMBB (enhanced Mobile Broadband)
Slice suitable for the handling of 5G enhanced Mobile broadband, useful, but not limited to the general consumer space mobile broadband applications including streaming of High Quality Video, Fast large file transfers etc. It is expected this SST to aim at supporting high data rates and high traffic densities as outlined in Table 7.1-1 "Performance requirements for high data rate and traffic density scenarios" in TS 22.261

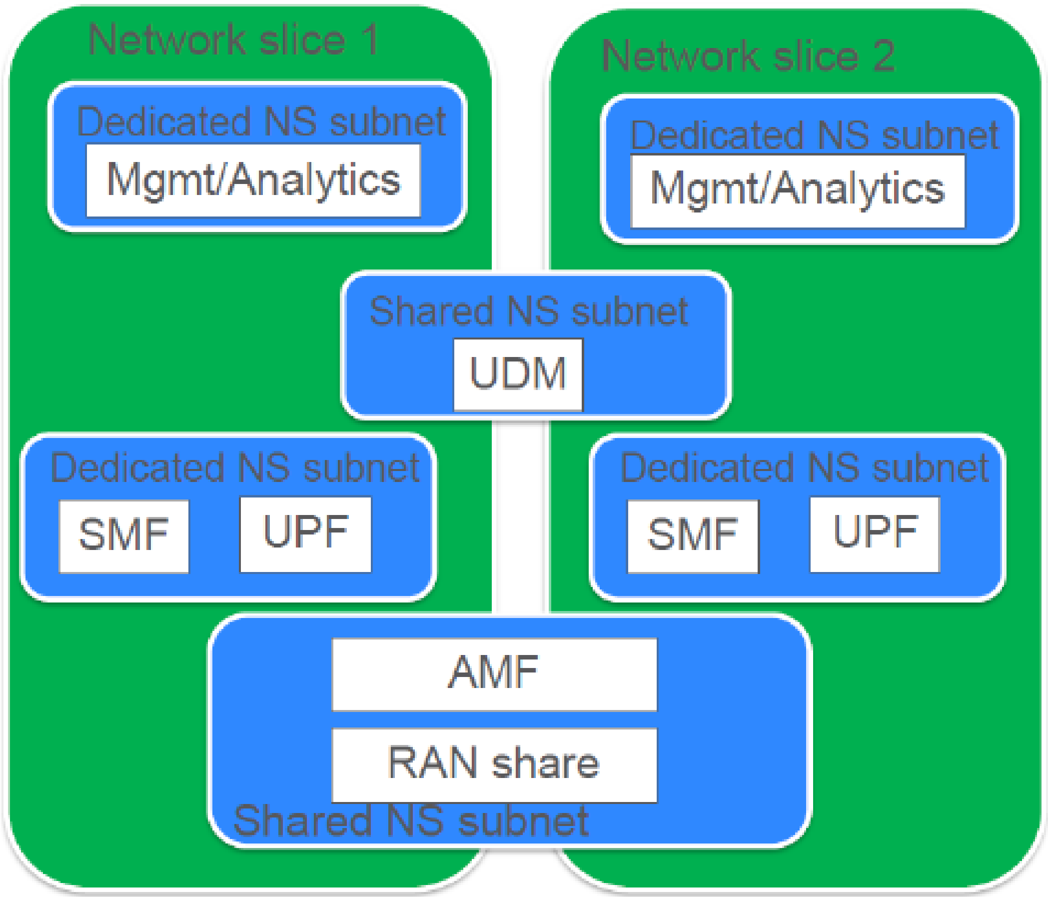
SST = 2, URLLC (Ultra-Reliable Low Latency Communication)
Supporting ultra-reliable low latency communications for applications including, industrial automation, (remote) control systems. This SST is expected to aim at supporting the requirements in Table 7.2.2-1 "Performance requirements for low-latency and high-reliability services." in TS 22.261 related to high reliability and low latency scenarios

SST = 3, MIoT (Massive IoT), mMTC (massive Machine Type Communication)
Allowing the support of a large number and high density of IoT devices efficiently and cost effectively.

CARACTERÍSTICAS DE NETWORK SLICING

- Logical network managed by a provider
- Enabler for services, not a service
- Mobile and fixed
- Resources may be physical or virtual, dedicated or shared
- Independent/"Isolated" but may share resources
- May integrate services from other providers, facilitating e.g. aggregation and roaming
- May include management functions and possible exposure of control/management to customer

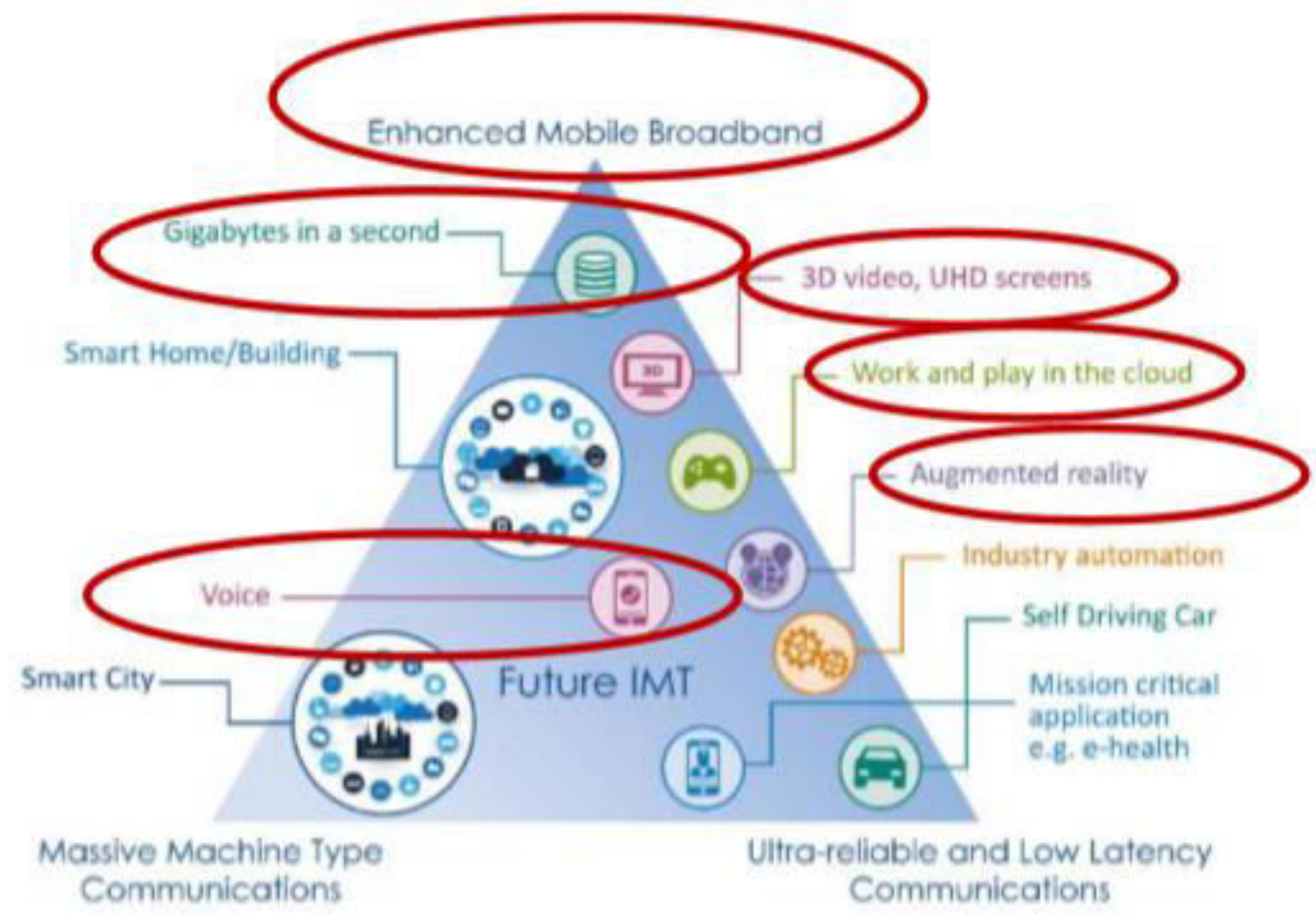
NETWORK SLICING SUBNET



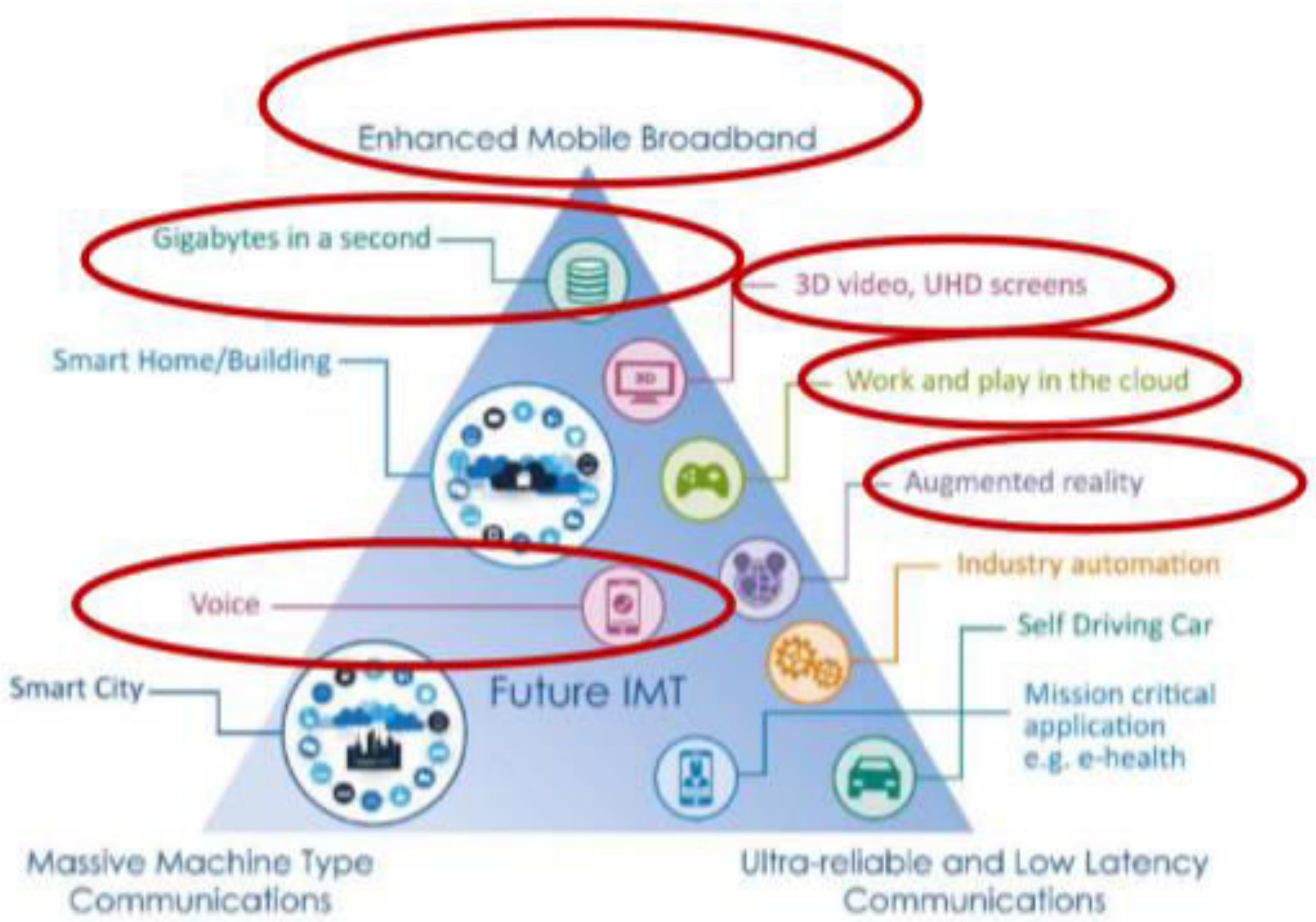
Network slice subnet is a constituting part of one or several network slices, consisting of a set of network resources configured together. It is created, changed and removed by management functions.

- Unlike network slices, network slice subnets do not serve a business purpose of their own, only as a member of a network slice
- Network slice subnets can be dedicated to a network slice or shared by several
- Network slice subnets may have other network slice subnets as its constituting parts
- Network slice subnets are formed because there is a need to life cycle them as a separate entity, or to enable sharing of network functions across network slices

NETWORK SLICING - eMBB



NETWORK SLICING - eMBB



NETWORK SLICING - eMBB

Classic Mobile Broadband

- Internet / Intranet access
- OTT services / Corporate services
- Video, audio, gaming, work-in-cloud....
- 7 billion people → x billion smartphones
- Coverage everywhere
- High capacity in urban areas
- Super-high capacity at e.g. large outdoor/indoor events

Voice over 5G

- IMS based Voice and Video over 5G
- ..or will operators use only Voice over LTE?

Broadband-to-the-Home via 5G

- 5G UE as Home Router
- Fixed Wireless Access (FWA)
- Fixed Mobile Convergence (again...)

High Definition Media streaming

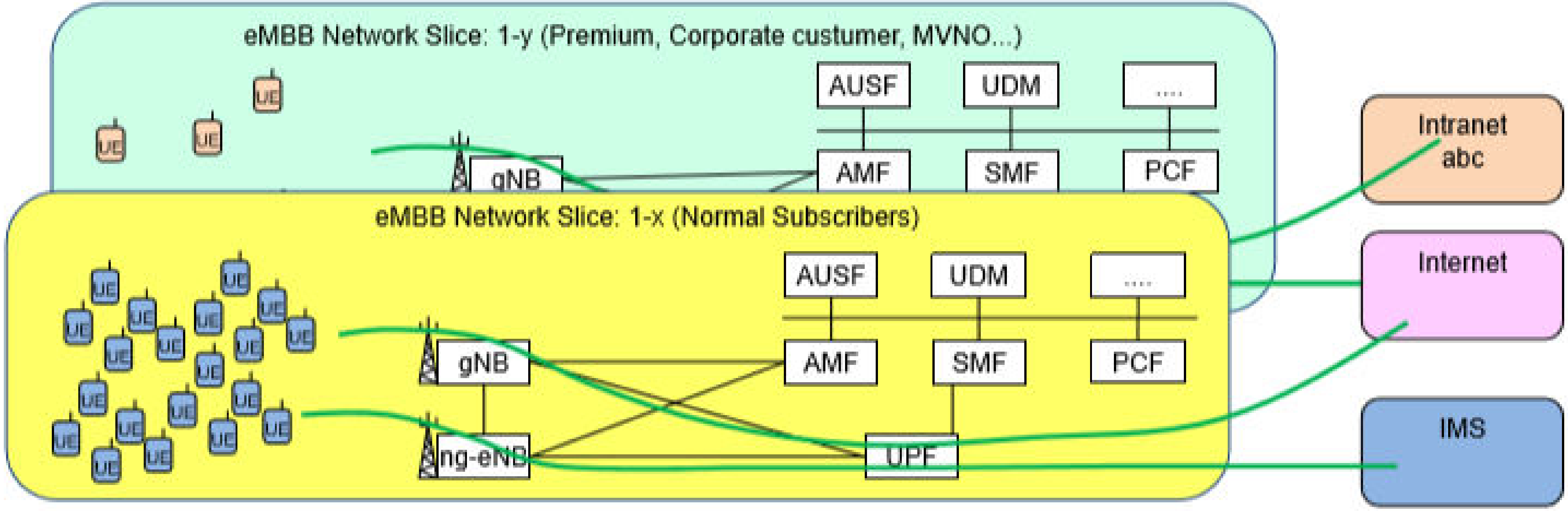
- 4K video
- 3D video
- Virtual and Augmented Reality
- Caching content closer to UE
  → Multi-access Edge Computing (MEC)

Local Area Data Networks

- Special content in local areas
- Stadiums / shopping or convention centres
- High density of users and traffic

...and others...

NETWORK SLICING - eMBB



- Smartphones etc
- 100 000's UEs per km2
- 1000's Gb/s per km2
- High peak rates
- Normal mobility
  - except FWA

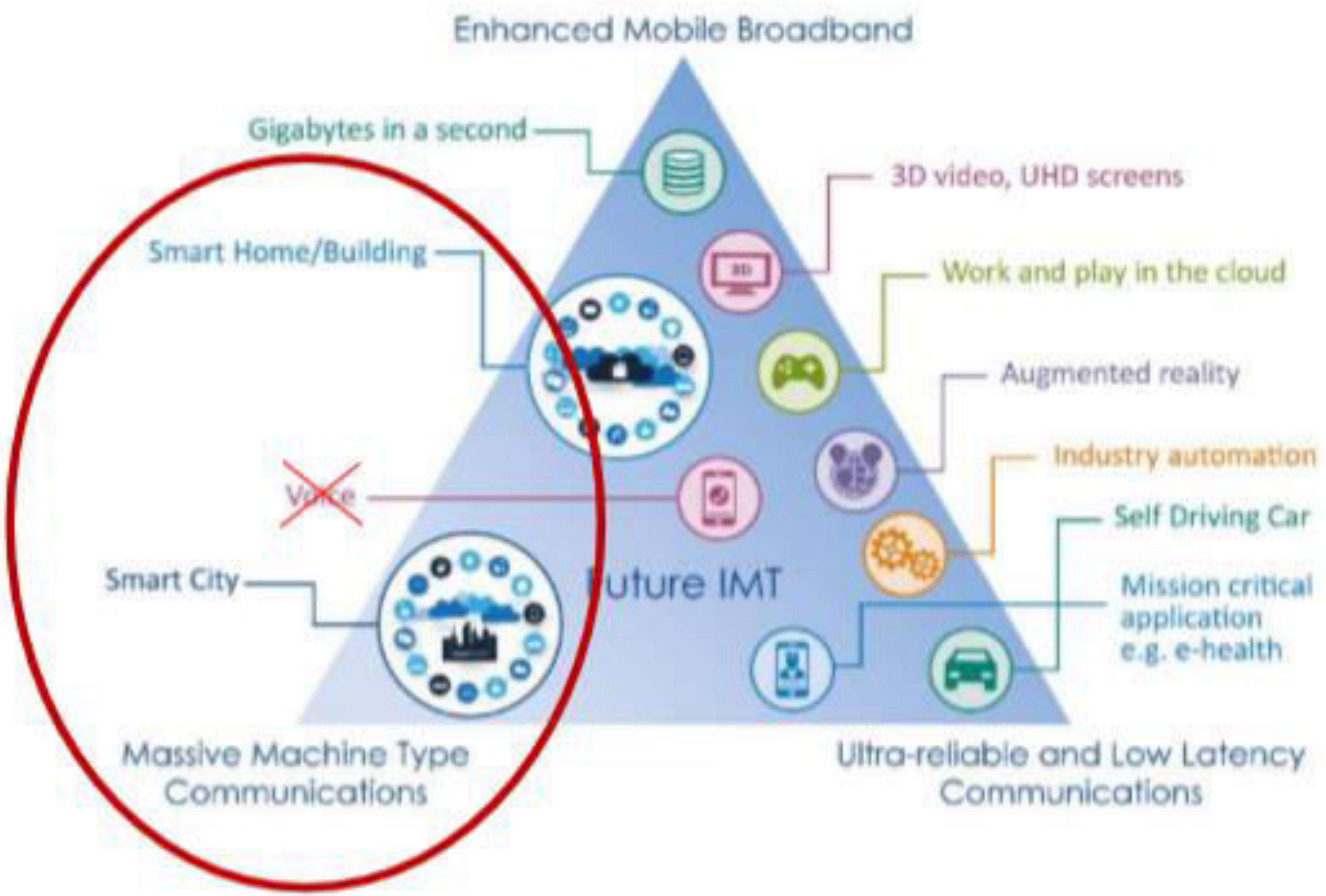
- Coverage everywhere - Macrocells
- High capacity – Small cells
- Carrier Aggregation, Dual Connectivity
- Massive MIMO, Beamforming
- Tight interworking with E-UTRA
- Use of unlicenced spectrum
- Aggregation with WiFi
- **Slice of RAN resources**

- High capacity in UPFs and transport NW
- Use of multiple Session Anchors (UPFs)
- Use of Multi-Access Edge Computing (MEC)
- **Slice of Core NW resources**

eMBB: Enhanced Mobie Broadband
FWA: Fixed, Wireless Access
MIMO: Multiple Input, Multiple Output
MVNO: Mobile Virtual Network Operator

Observar el UP para servicios de Internet y para IMS. Cual es la diferencia?

NETWORK SLICING - mMTC



Observar el UP para servicios de Internet y para IMS. Cual es la diferencia?

NETWORK SLICING - mMTC

Smart cities
- Traffic monitoring and control
- Smart parking
- Information services

Home
- Heating/cooling/light control
- Utility meters (electricity, gas...)
- Alarms
- Access control
- Automated shopping

Energy
- Turbines/windmills/generators/ /sub-station control and monitoring
- Backup generators

Transportation
- "Non-URLLC V2X"
- Tolls
- Navigation
- Traffic / Fleet management
- Logistics / Tracking

Retail services
- Vending machines
- Payment terminals

Industry
- "Non-URLLC automation"
- Sensors, meters, actuators

Healthcare
- "Non-URLLC healthcare"
- Patient monitoring
- Home monitoring

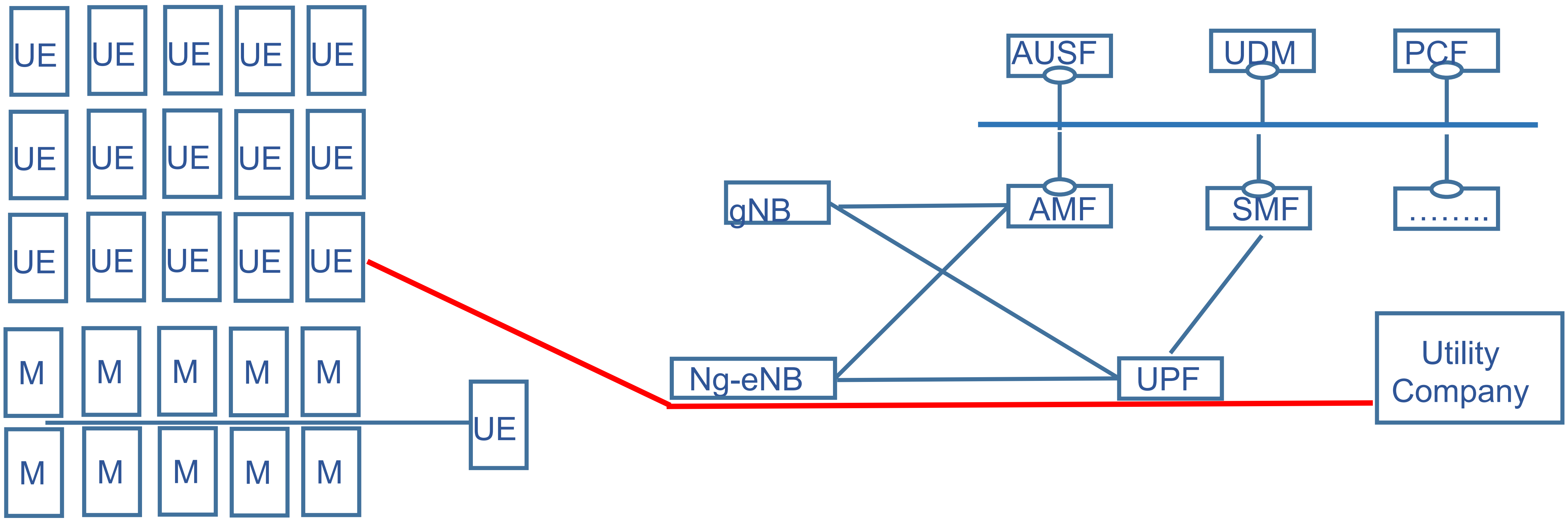
Security
- Surveillance
- Alarms
- Tracking
- Environmental sensors

Personal
- Personal Area Networks
- Entertainment equipment
- Home network integration

...and others...

Discutir el estado del arte de IOT

NETWORK SLICING – mMTC-Ejemplo de medidor remoto



Discutir el estado del arte de IOT

NETWORK SLICING - mMTC

- 1 000 000's per km2
- Low complexity
- Power Save Mode?
- MICO mode?
- De-register after communication?
- Little data, low rates, non-RT
- Stationary
- Some via IoT-GW (UE)
  - Capillary NW (WiFi, Bluetooth, ZigBee...)

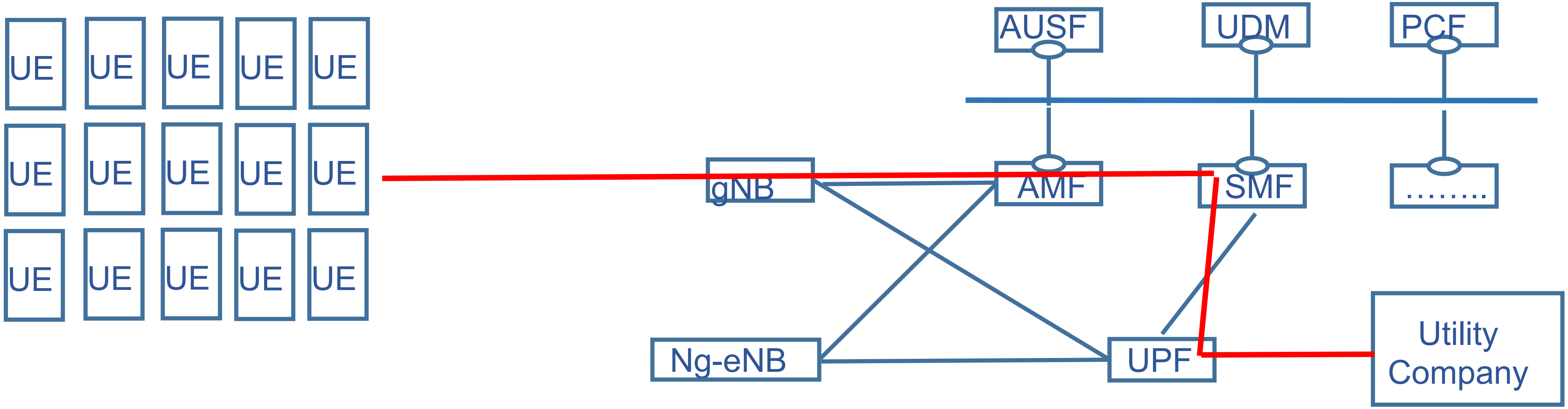
- Coverage everywhere – Macrocells
- LPWA
- Use 4G NB-IoT or LTE-M?
  - deep / extended coverage
  - relaxed radio requirements
  - simple modulation
  - repetition of data
  - Extended Access Barring
  - long DRX cycles (eDRX)
- Most UEs in IDLE mode
  → not known in RAN
- **Slice of RAN resources**

- Lots of registered UEs
- Moderate User Plane capacity
- Expected UE Behaviour and Mobility Pattern info can be sent AF → 5GC → RAN
- **Slice of Core NW resources**

DRX: Discontinous Reception
eMTC: Enhanced Machine Type communication
LPWA: Low Power Wide Area
LTE-M: LTE for Machine-Type Communication
MICO: MobileInitiated Communication Only
NB IoT: Narowband IoT
Non RT: Non real Time
IoT Gw: IoT Gateway

Discutir el estado del arte de IOT

NETWORK SLICING – mMTC. Ejemplo de tracking



- UE = Tracking devices
- How many?
- Low complexity
- Little data, low rates
- Infrequent reporting
  - Only after polling from server?
- Mobile!

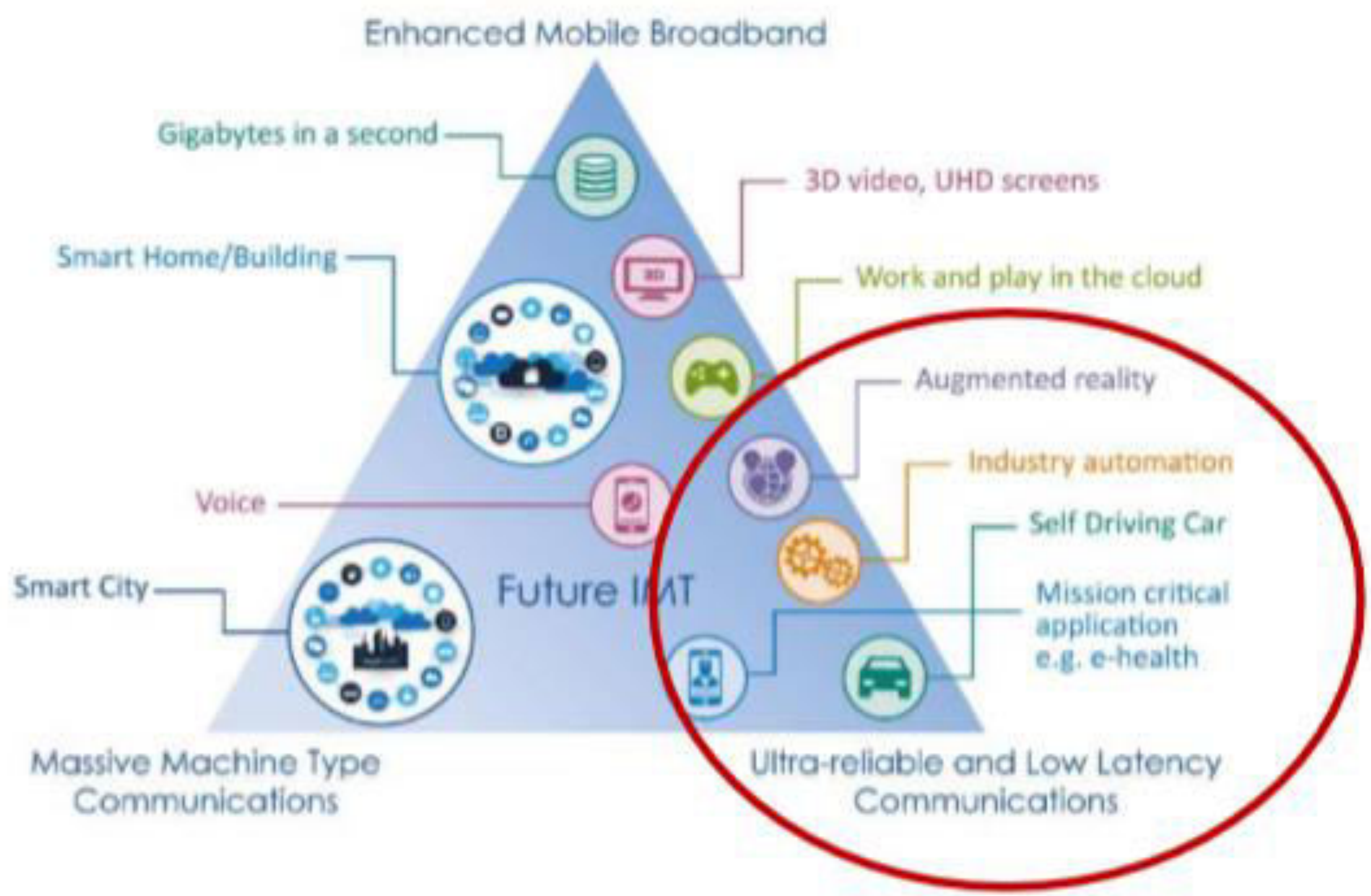
- Coverage everywhere – Macrocells
- LPWA
- Data over NAS?
- Data in SMS?
- Use 4G NB-IoT or LTE-M?
- Most UEs in IDLE mode
  → not known in RAN
- **Slice of RAN resources**

- User plane capacity….?
- Expected UE Behaviour and Mobility Pattern info can be sent AF → 5GC → RAN
- Session: (no DRBs and N3-tunnels needed?)
- **Slice of Core NW resources**

DRX: Discontinous Reception
eMTC: Enhanced Machine Type communicatio
LPWA: Low Power Wide Area
LTE-M: LTE for Machine-Type Communication
MICO: MobileInitiated Communication Only
NB IoT: Narowband IoT
Non RT: Non real Time
IoT Gw: IoT Gateway
SMSF: SMS Function

Discutir el estado del arte de IOT

NETWORK SLICING – Ultra-Reliable and Low Latency Communication



Cual es la latencia máxima admisible? Y qué ocurre en el borde de la red?

NETWORK SLICING – Ultra-Reliable and Low Latency Communication

Industry Automation

- Factory cell automation
- Process control and monitoring
- Meters, sensors, actuators...
- Control systems
- Automated unmanned vehicles
- Remote and inaccessible locations (e.g. mines)
- Downtime not acceptable

Utility sector (electricity, gas, water)

- Reporting, Monitoring, O&M
- Fault handling, isolation, backup

Healthcare

- Patient monitoring
- Home monitoring
- Scheduled and unscheduled reporting
- Remote examination
- Remote surgery (1 ms delay, 99.999% reliability)

V2X – Vehicle-to-Everything

- V2V, V2P, V2I, V2N
- Automated and remote driving
- Collision warning / avoidance
  - latency 10 ms (appl level)
- Vehicle platooning (25 ms latency)
- Sensor and state map sharing
- Collective Perception of Environment
- Dynamic ride sharing (invite pedestrian)
- Using Vehicle as relay for Internet access
- Status updates for service (motor, oil...)
- High velocities (up to 500 km/h)

Public Safety (Mission Critical Services)

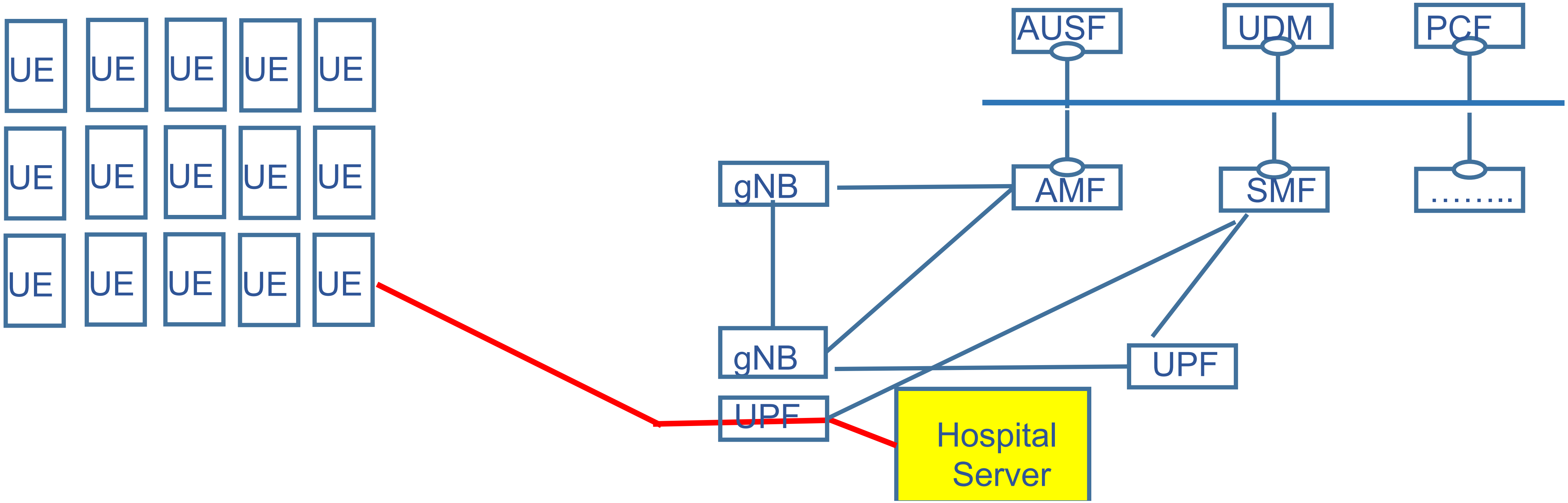
- Police, fire brigade, first responders
- Dispatchers
- MC Voice, Video and Data
- Call Groups, Multicast / Broadcast
- Direct Mode communication (also off-net)

V2I: Vehicle to Infraestructure
V2N: Vehicle to Network
V2P: Vehicle to Pedestrian
V2V: Vehicle to Vehicle

...and others...

Discutir el concepto de MEC y el transporte en la red de acceso

NETWORK SLICING – URLLC. Ejemplo de Hospital



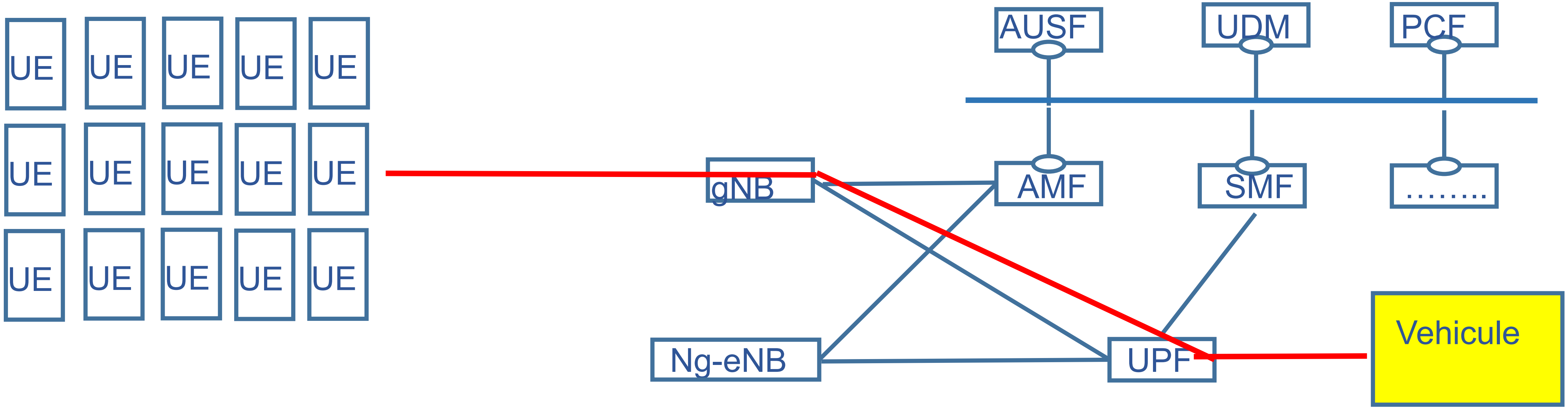
- Meters, sensors, actuators
- x per km2
- Stationary and limited mobility

- Reliable radio where URLLC is offered
- Suitable NR numerologies:
  - large sub-carrier spacing and short transmission timing
- Packet duplication
  - two RLC entities on different carriers
- **Slice of RAN resources**

- LADN with UPF at RAN site?
- **Slice of Core NW resources**

Discutir otro ejemplo de aplicación

NETWORK SLICING – mMTC. Ejemplo de Vehicule to anything



- UEs in Vehicles!
- 1 000s per km2
- Little data, low rates
- Frequent transmissions
- Device-to-device (D2D)
- Fully mobile!
- Speeds up to 500 km/h

- Coverage everywhere - Macrocells
- High capacity in cities/roads
- D2D requires sidelink channels
- **Slice of RAN resources**

- MEC used for some services
  -Expected UE Behaviour and Mobility Pattern info can be sent AF → 5GC → RAN
- **Slice of Core NW resources**

Discutir el estado del arte de IOT

Para qué virtualizar la Red?

- Baja de costos apalancado en las economías de escala de la industria del IT. (Manteniendo un Nivel de Servicio Carrier Class).
- Flexibilidad y rapidez para provisionar e iniciar servicios en diferentes lugares sin tener que instalar nuevos equipos.
- Mejorar el Time to Market
- Mejorar la eficiencia operacional basada en la ventaja de contar con una plataforma de red homogénea (física)
- Reducción de costos por: Reducción de consumo energético, espacio ocupado y una mejora en el network monitoring
- Innovar creando un ecosistema abierto que posibilite contar con nuevos proveedores.

Basado en la Fuente: ETSI EXPLAINING NETWORK FUNCTION VIRTUALIZATION
Prodip Sen Chair of the ETSI Industry Specification Group (ISG) on *NFV*
18/Marzo/2014

En qué consiste la virtualización de funciones de la red?

Es la combinación de dos conceptos:

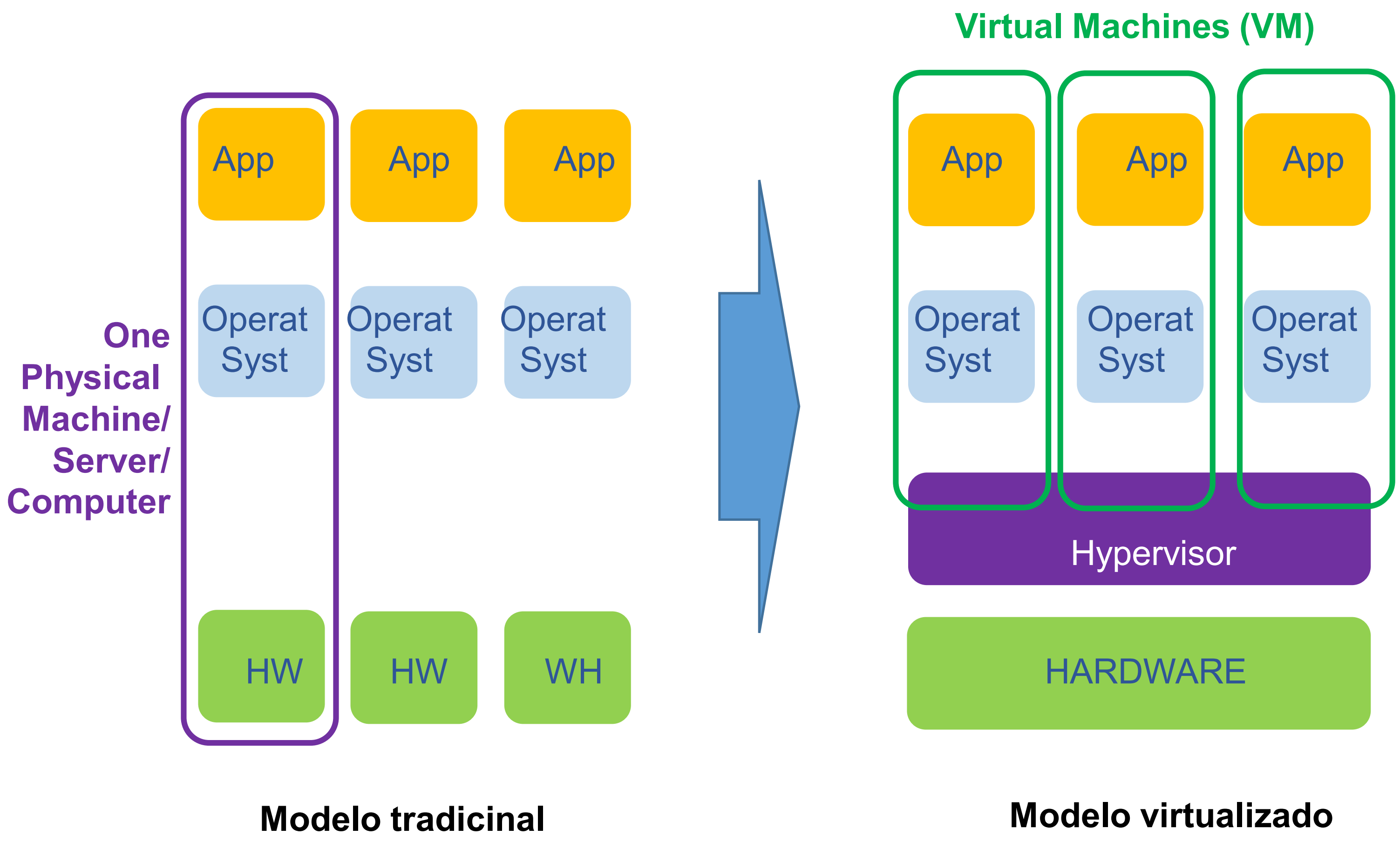
- NFV: Es la separación del hw del sw (soportando funciones de red en software sobre hardware de propósito general)
- SDN: Es la separación del plano de control del plano de datos, pudiendo cambiar el comportamiento de los conmutadores de forma externa.

Conjuntamente se pretende conseguir separar:

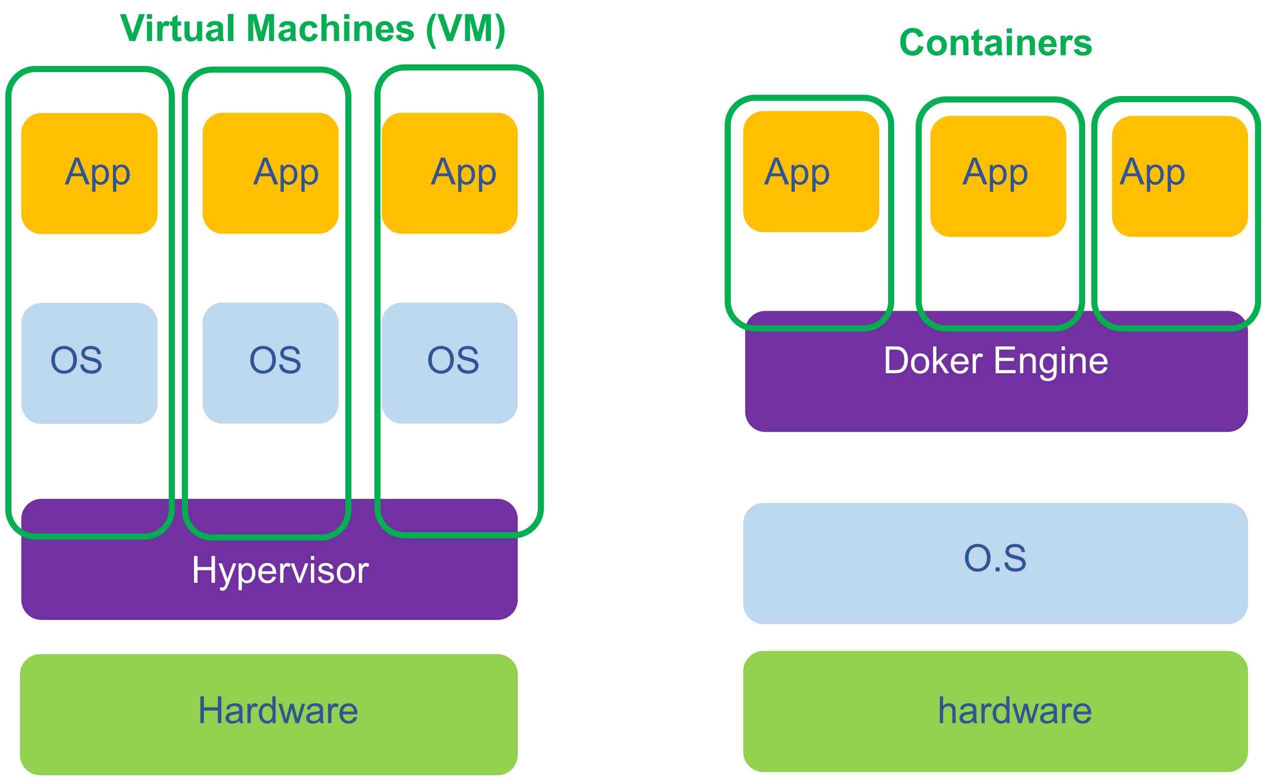
las funciones de red	la capacidad para albergarlas

pudiendo gestionarse y escalarse por separado

NETWORK VIRTUALIZATION- STACK DE VIRTUALIZACIÓN



NETWORK VIRTUALIZATION- VIRTUAL MACHINE VS CONTAINERS

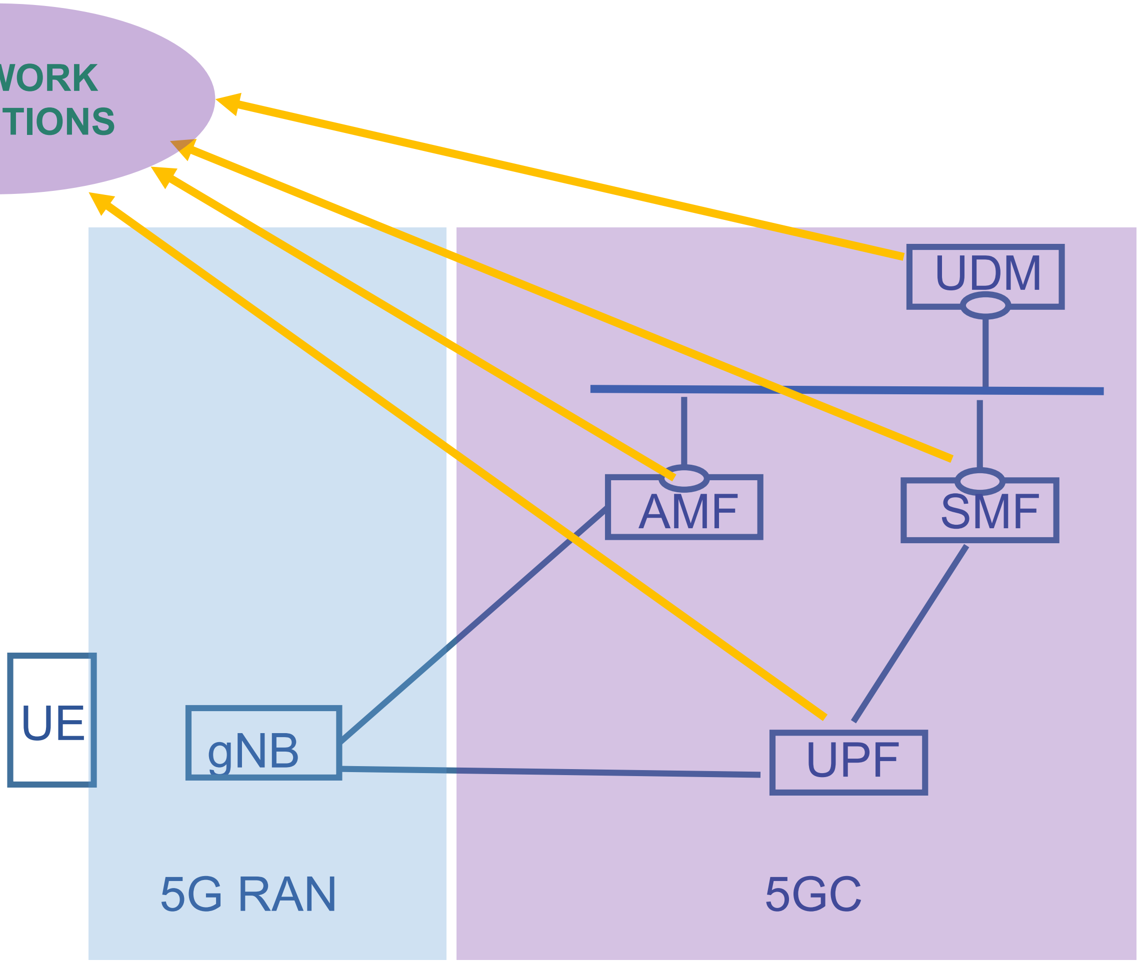


Pensar en una alternative a Docker

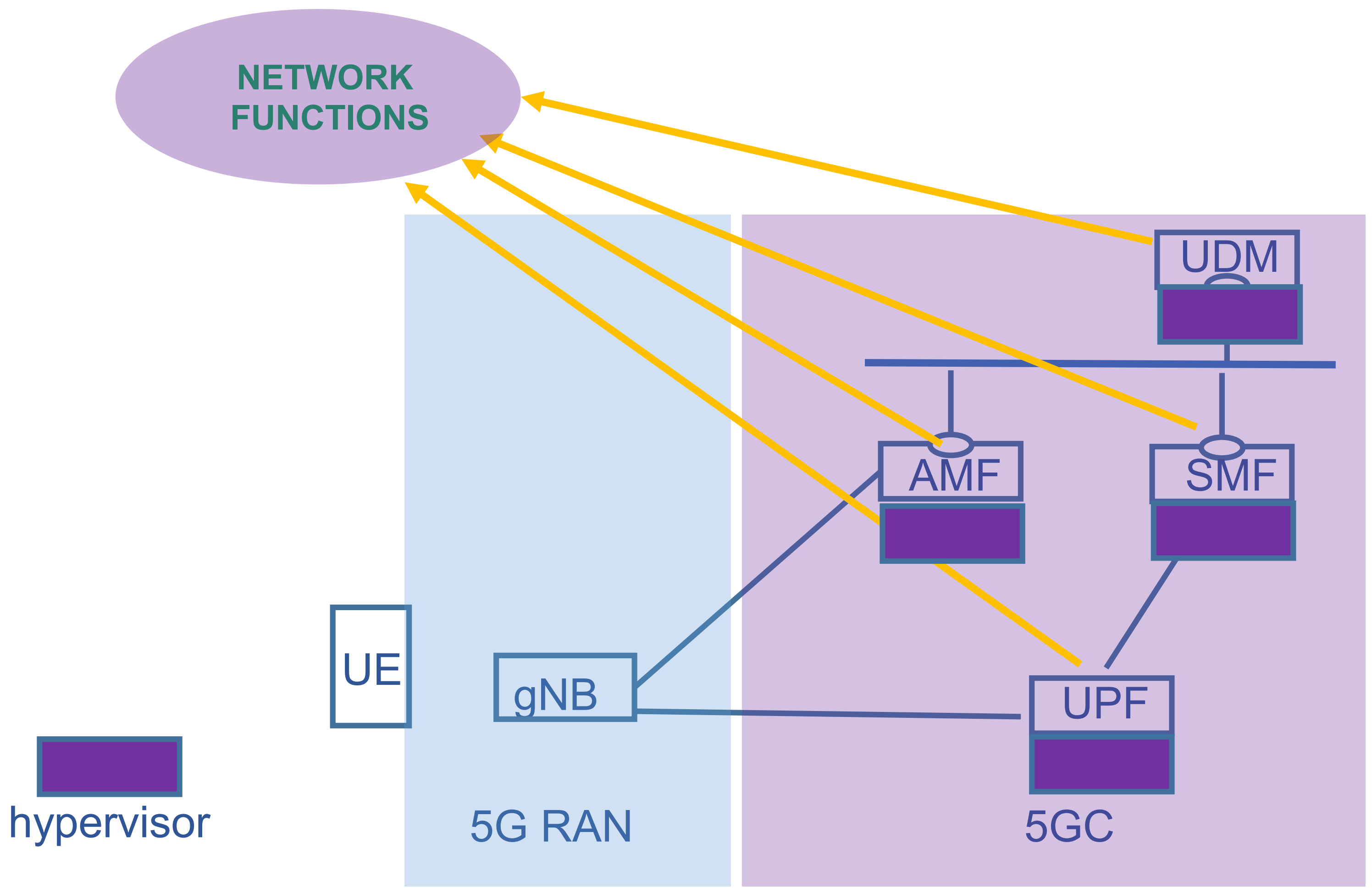
NETWORK VIRTUALIZATION- CORE NO VIRTUALIZADO

Problemas con las NF

- Escalabilidad
- Cambio en el patron de tráfico
- Redundancia
- Hardware específico
- Locaciones estáticas

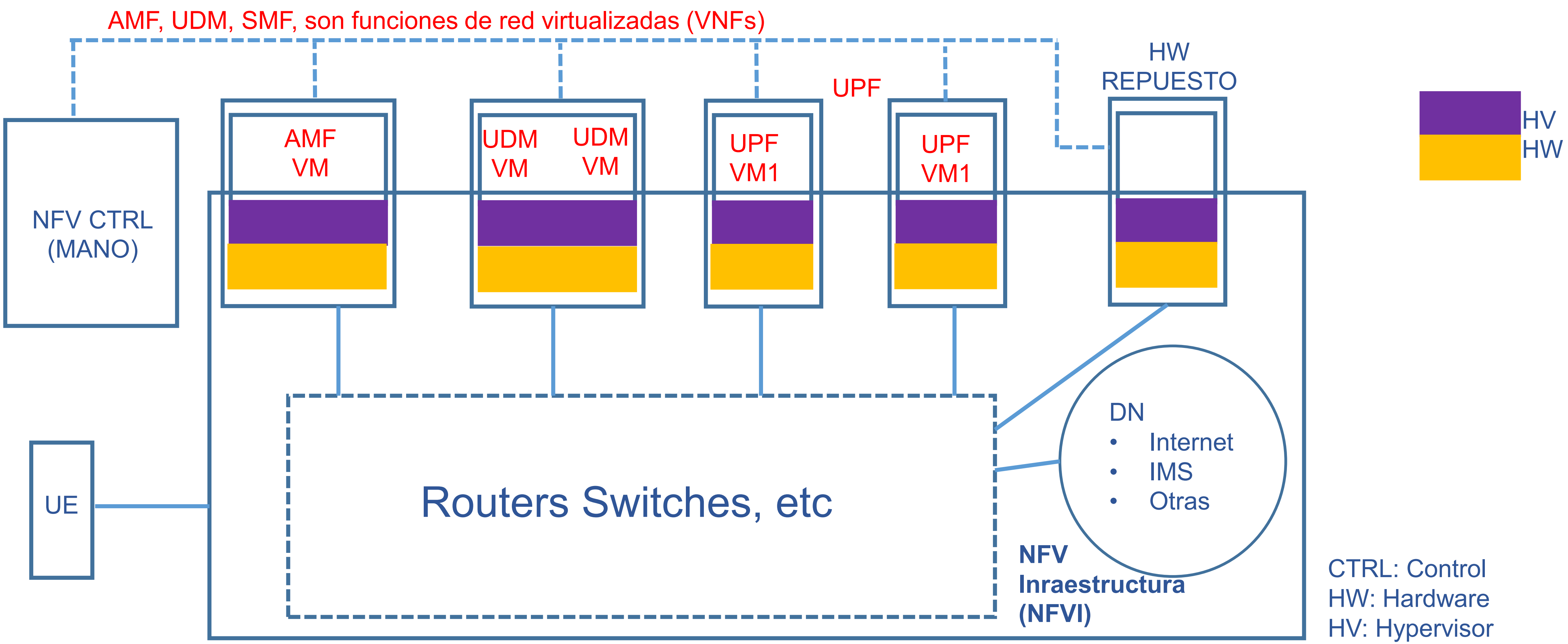


NETWORK VIRTUALIZATION- CORE VIRTUALIZADO



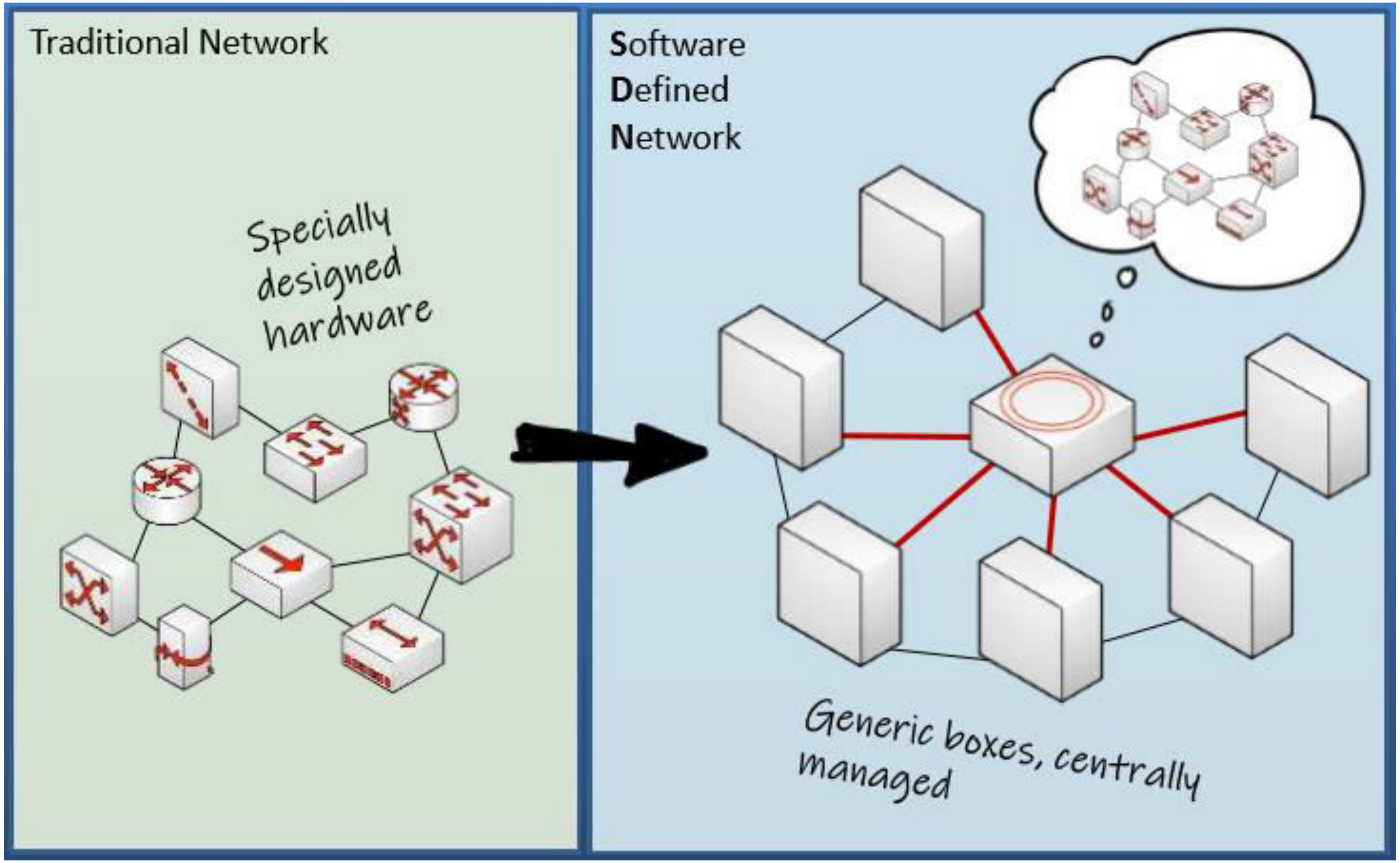
Por qué el gNB no aparece virtualizado?

NETWORK VIRTUALIZATION- NFV EN 5GC

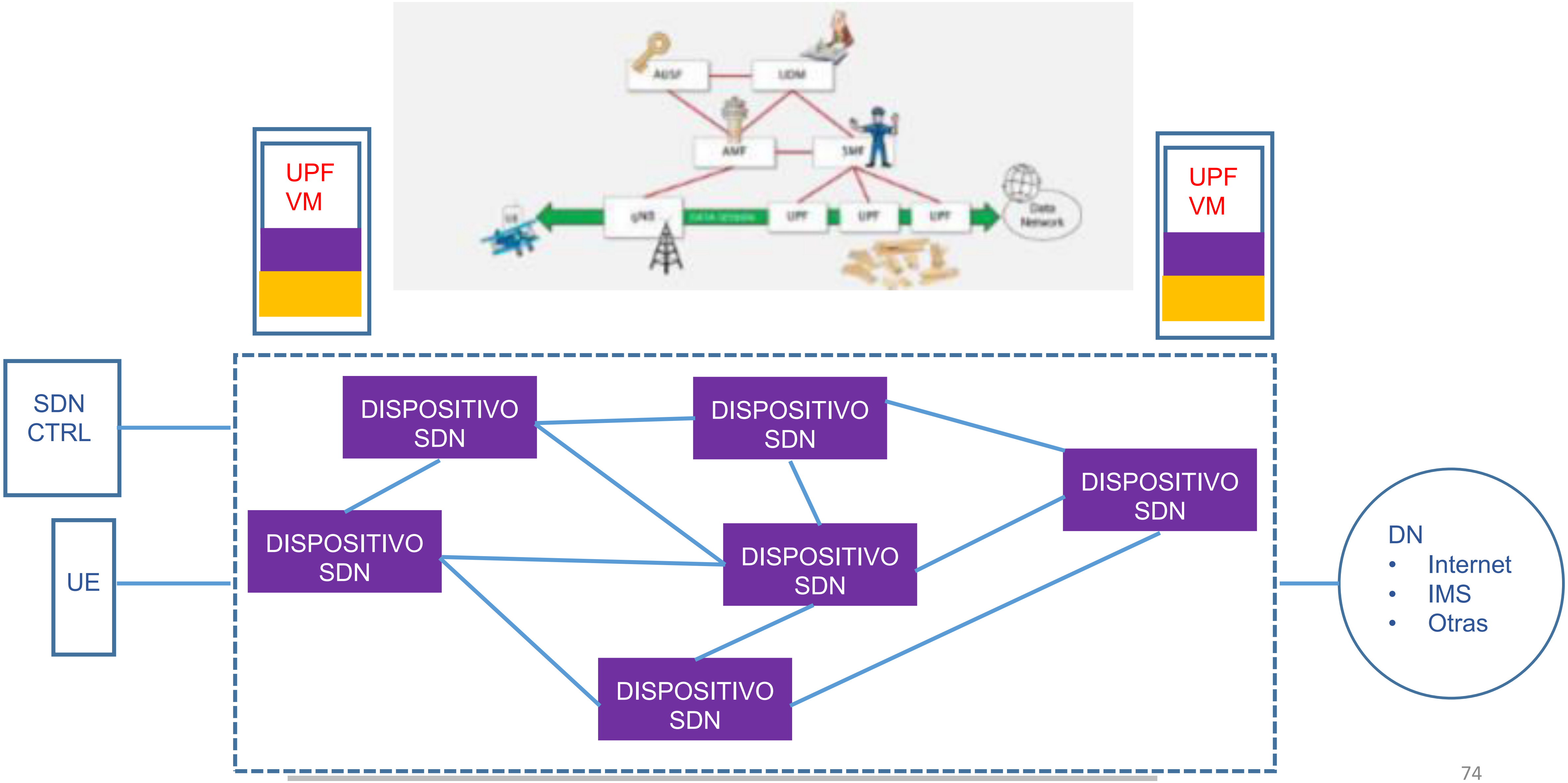


CTRL: Control
HW: Hardware
HV: Hypervisor
MANO: Management and Orchestation

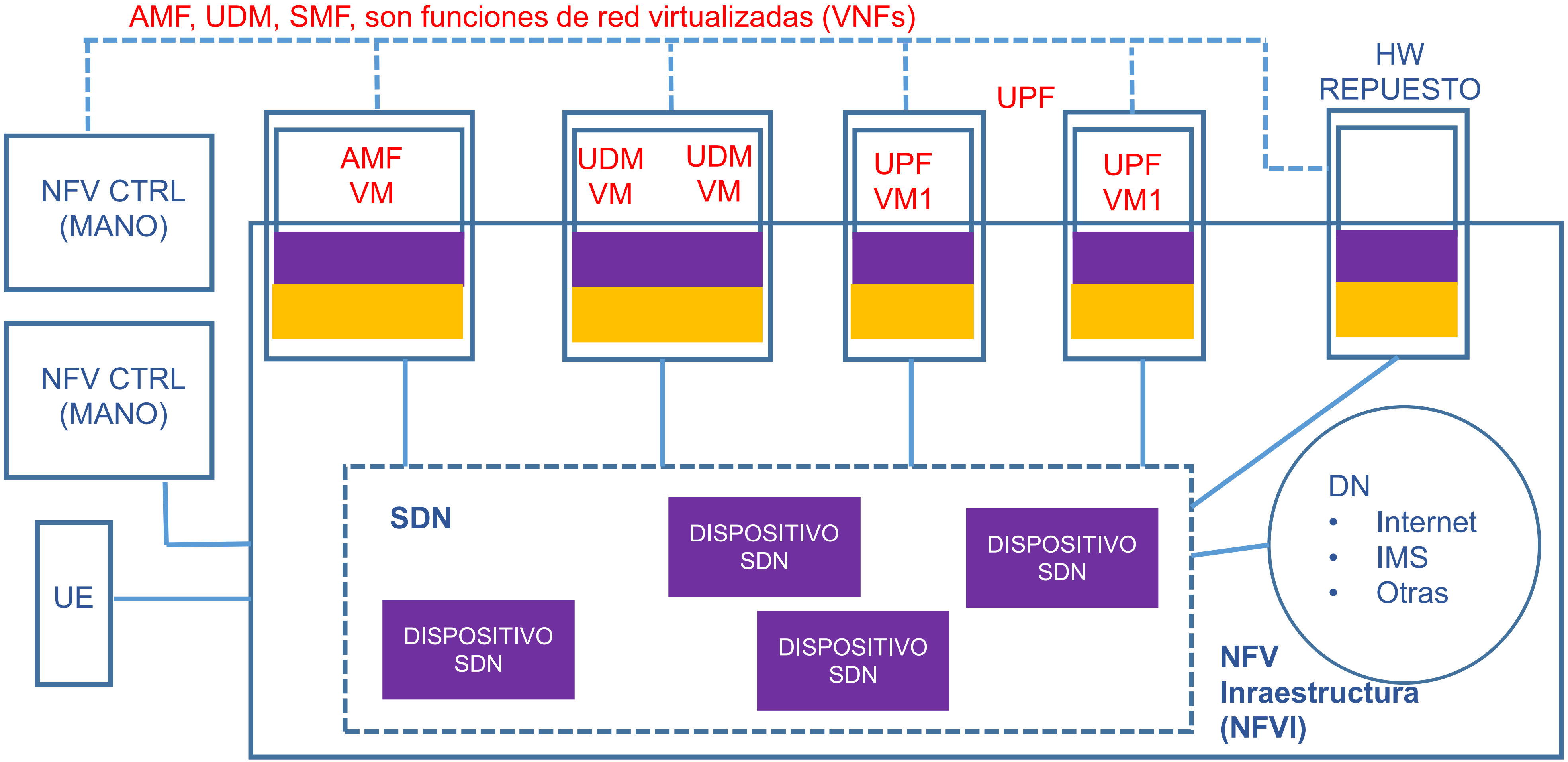
SDN. SOFTWARE DEFINED NETWORK



5G SDN. SOFTWARE DEFINED NETWORK



NETWORK VIRTUALIZATION- NFV EN 5GC



CTRL: Control
HW: Hardware
HV: Hypervisor
MANO: Management and Orchestation

REDES DE QUINTA GENERACIÓN
Curso Nivel 2
Módulo 3

CePETel

Prof. José Luis Pellegrino

MODULO 1
Arquitectura de la red de Red de Acceso.
Protocolos: Capa física, MAC, RLC, PDCP, Capas altas.
Ancho de banda asociado a cada capa.
Modelo de Centralización y de Distribución.
CPRI.

MODULO 2
Arquitectura del Núcleo en redes SA
Concepto de Slicing
Entidades, Interfaces protocolos.
Overlay 5GC con EPC

MODULO 3
La red de transporte en 5G.
Requerimientos de ancho de banda.
Requerimientos de latencia. TSN.
Desagregación de la Red de Acceso.

MODULO 4
Open RAN
Arquitectura.
Modelo
Casos y desafíos

LTE & EPC

MODULO 5

5G Signalling

NWDAF Network Data Analytics Function

SEPP Seurity Edge Protection Proxy

MODULO 6

Automatización

SDN

SON

RIC

RESUMEN DE CARACTARÍSTICAS DE LA RAN –IMPACTO EN EL TRANSPORTE

BANDAS- RESUMEN

Main spectrum bands	700MHz–2.6GHz	3.5GHz, 5GHz	27.5–31GHz ('28GHz')	37–42.5GHz ('39 GHz')	70–80GHz ('E-band')
Usage	Traditional mobile bands	New bands to be released for 5G			
			mmWave		
Multiples of assignments	Tens of MHz		100s of MHz		
Amount available	<1GHz		45GHz		
Maximum cell radii	Tens of kilometers	~1km	Tens to hundreds of meters, depending on LoS		

NEW RADIO-EVOLUCIÓN DE LTE

2009	2011	2016	2017	2018	2019	2020	2021
Rel-8	Rel-10	Rel-13	Rel-14	Rel-15	Rel-16	Rel-17	

Mobile Broadband
VoLTE

Need for more!
New use cases
Internet of Things (MTC)
Device to Device (ProSe)
Technical Evolution
WiFi everywhere

LTE → LTE Advanced → LTE Advanced Pro → LTE Advanced Pro Cont.

New Radio NR.

1,4-20 MHz Carriers
FqNeed for more!
New use cases
Internet of Things (MTC)
Device to Device (ProSe)
Technical Evolution
WiFi everywhere

- Carrier Aggregation
- Dual Connectivity
- Coordinated Multipoint
- HetNets /Small Cells
- Advanced MIMO and modulation
- New UE categories
- NB-IoT (narrow carriers- 180 KHz)
- LTE-M
- Licensed Assisted Access (LWA)
- LTE WAN Aggregation
- Enhancements improvements

- **ANCHO DE BANDA**
- **LATENCIA**
- **SINCRONISMO**
- **TRANSPORTE**

NETWORK SLICING

SST = 1, eMBB (enhanced Mobile Broadband)
Slice suitable for the handling of 5G enhanced Mobile broadband, useful, but not limited to the general consumer space mobile broadband applications including streaming of High Quality Video, Fast large file transfers etc. It is expected this SST to aim at supporting high data rates and high traffic densities as outlined in Table 7.1-1 "Performance requirements for high data rate and traffic density scenarios" in TS 22.261

SST = 2, URLLC (Ultra-Reliable Low Latency Communication)
Supporting ultra-reliable low latency communications for applications including, industrial automation, (remote) control systems. This SST is expected to aim at supporting the requirements in Table 7.2.2-1 "Performance requirements for low-latency and high-reliability services." in TS 22.261 related to high reliability and low latency scenarios

SST = 3, MIoT (Massive IoT), mMTC (massive Machine Type Communication)
Allowing the support of a large number and high density of IoT devices efficiently and cost effectively.

DISTINTOS SERVICIOS
DISTINTAS PARTES DE RAN

- **ANCHO DE BANDA**
- **LATENCIA**
- **SINCRONISMO**
- **TRANSPORTE**

RLEASE 15 DE 3GPP. LA BASE

NUEVAS TECNOLOGÍAS
EFICIENCIA ESPECTRAL
NUEVAS BANDAS , MAYOR BW

- **ANCHO DE BANDA**
- **LATENCIA**
- **SINCRONISMO**
- **TRANSPORTE**

LA NECESIDAD DEL TRANSPORTE

DESAFÍOS PARA LA RED DE TRANSPORTE

La introducción de la nueva tecnología de radio 5G (NR) está permitiendo nuevos casos de uso inalámbricos como banda ancha móvil mejorada (eMBB), comunicaciones de baja latencia ultra confiables (uRLLC), comunicaciones de tipo máquina masiva (mMTC) y acceso inalámbrico fijo de alta velocidad (FWA)

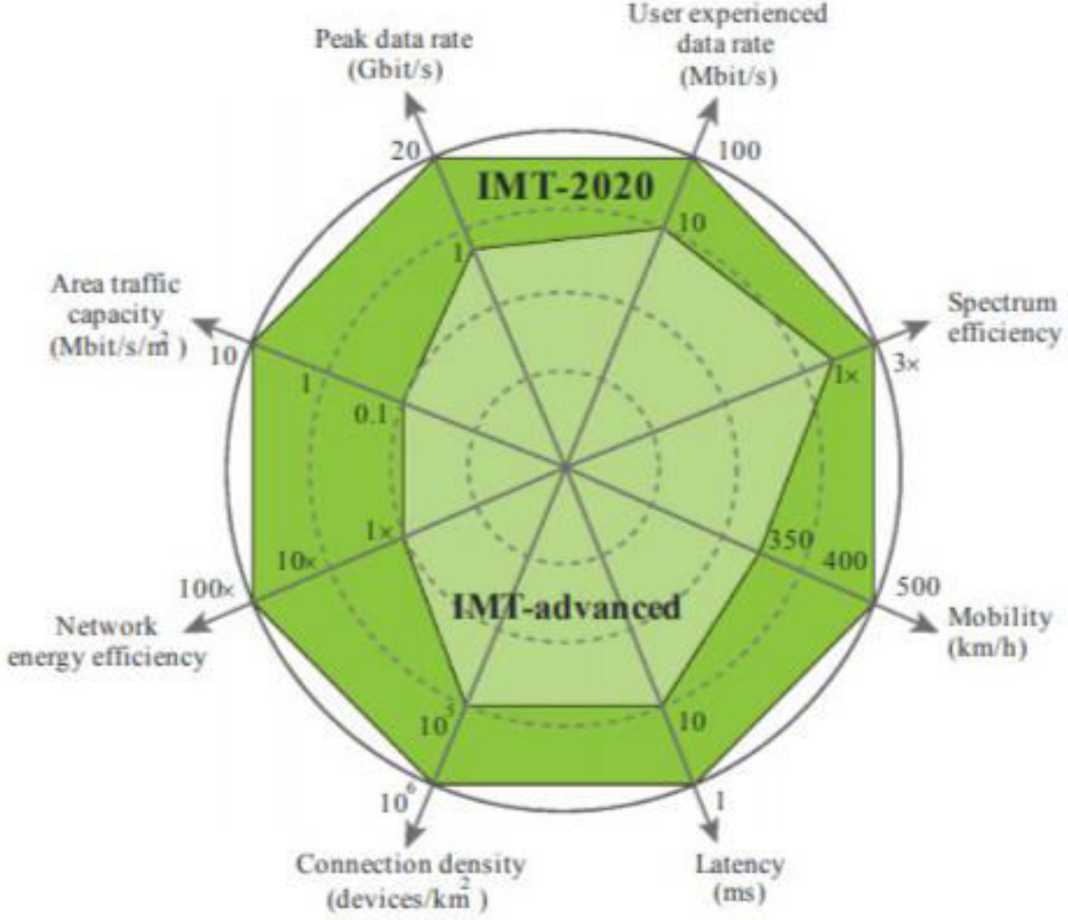
Requisitos nuevos y más estrictos a las redes de transporte subyacentes que admiten la red 5G.

Para ofrecer con éxito una experiencia de usuario 5G satisfactoria, las futuras redes de transporte deberán proporcionar mejoras significativas en las velocidades máximas de datos, la capacidad de tráfico de área, la latencia, la sincronización, la seguridad, la automatización y las nuevas interfaces. Por ejemplo, la aplicación de la tecnología de antenas masivas de múltiples entradas y múltiples salidas (mMIMO) y nuevas técnicas de codificación, junto con anchos de banda de canal extremadamente amplios que son posibles gracias al espectro de ondas milimétricas (mmWave), ha producido un aumento de diez veces en las velocidades de datos máximas, de 1 Gbps actual a 10 Gbps y más. De manera similar, la nueva estructura de marco 5G NR ha reducido drásticamente la latencia de 10 milisegundos (o más) a menos de 1 milisegundo, en comparación con la tecnología 4G anterior.

De 1 Gbps actual a 10 Gbps y más

De 10 milisegundos (o más) a menos de 1 milisegundo

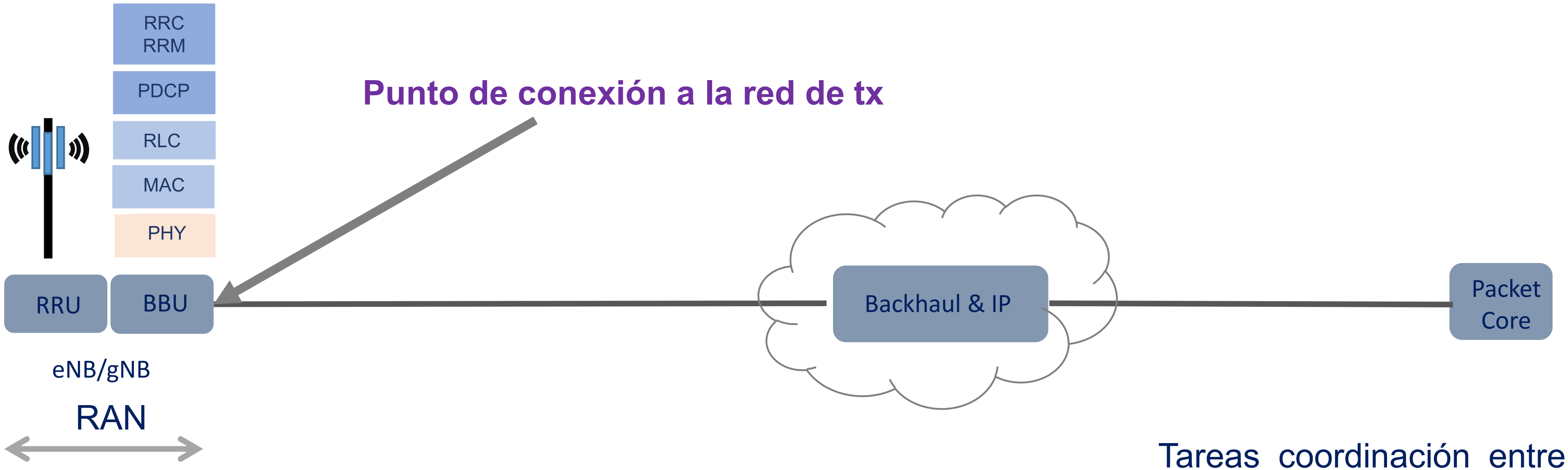
DESAFÍOS PARA LA RED DE TRANSPORTE-IMT 2020



Para cumplir con estas nuevas capacidades y superar las pérdidas de propagación y penetración asociadas con el espectro de ondas milimétricas, los operadores también deberán implementar topologías de red mucho más densas, lo que requerirá inversiones de capital sustanciales.

De 1 Gbps actual a 10 Gbps y más
De 10 milisegundos (o más) a menos de 1 milisegundo

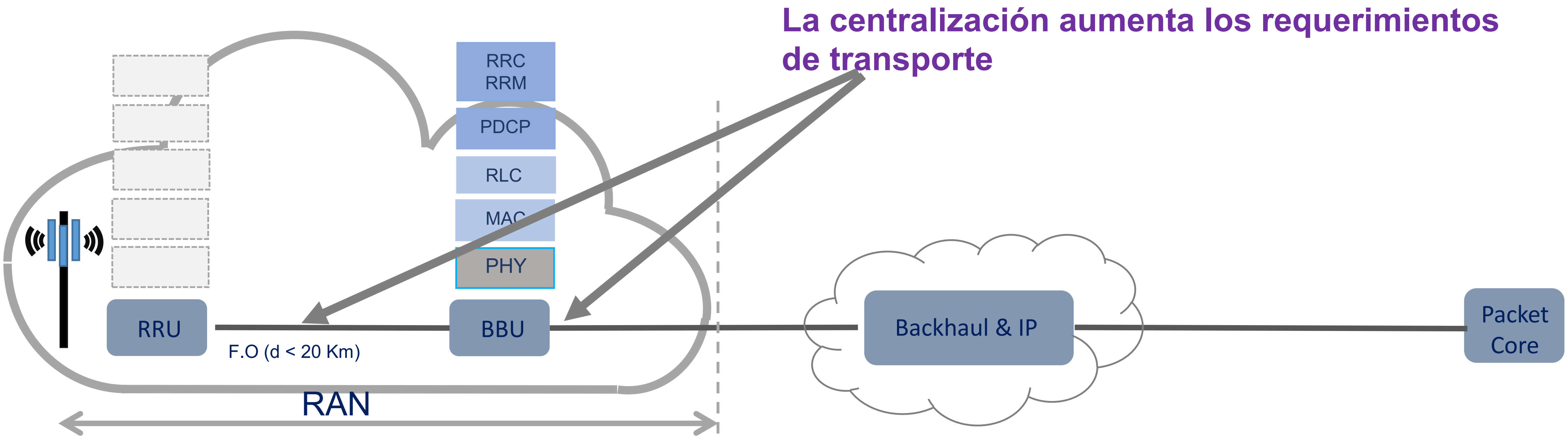
DISTRIBUTED RAN



- Solución RAN monolítica provista por un solo vendor.

Tareas coordinación entre radio bases es limitada (Interfaz X2 de LTE).

CENTRALIZED RAN

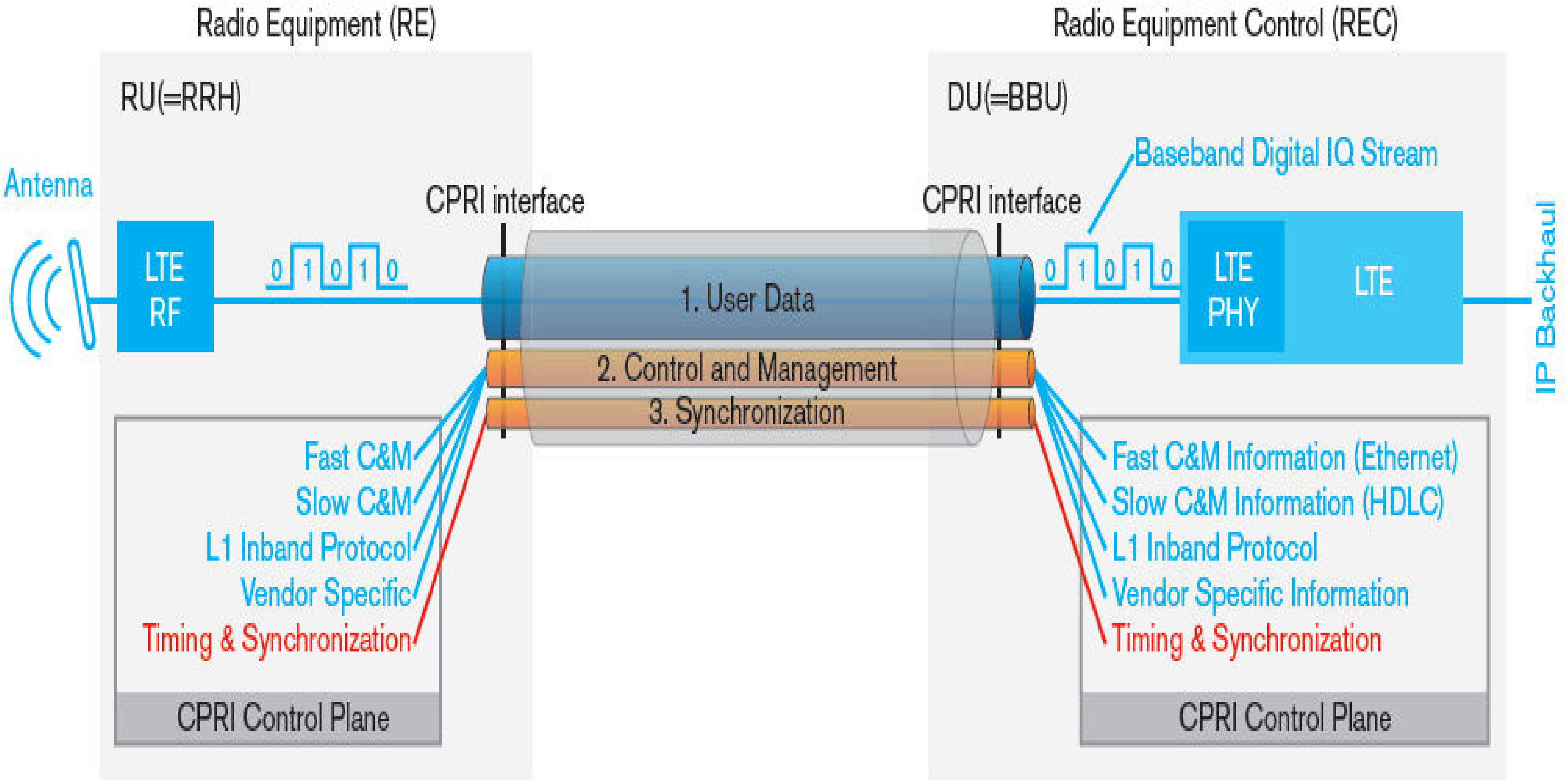


- Solución RAN provista por un solo vendor.
- El máximo grado de desagregación de la RAN es RRU y BBU (modelo granjeado)
- Pool de BBUs en un mismo lugar. BBUs colocalizadas en una central
- RAN localizada en el edge y Packet Core centralizado.
- Solo la capa de radio en el sitio.
- Todas las capas de radio desplegadas en un entorno < 20 kms (Fronthaul).
- Se simplifica el backhaul y el sincronismo
- Solución baremetal.
- CPRI propietario

eNB = RRU +BBU

Sigue siendo válido en 5G?

CPRI

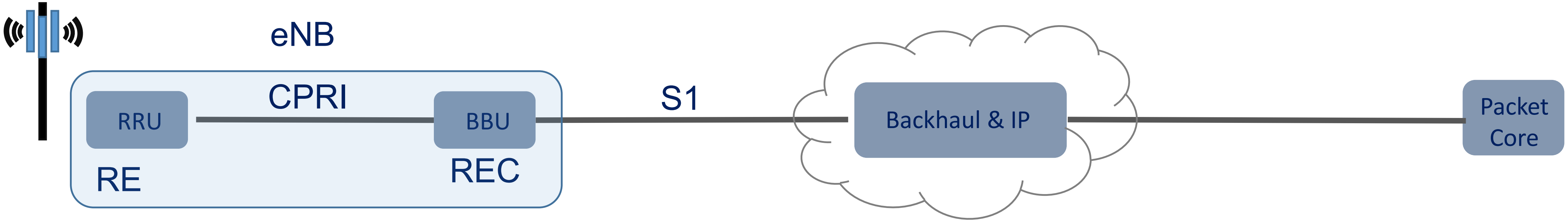


Qué precio en términos de ancho de banda implica el uso de señales I & Q.

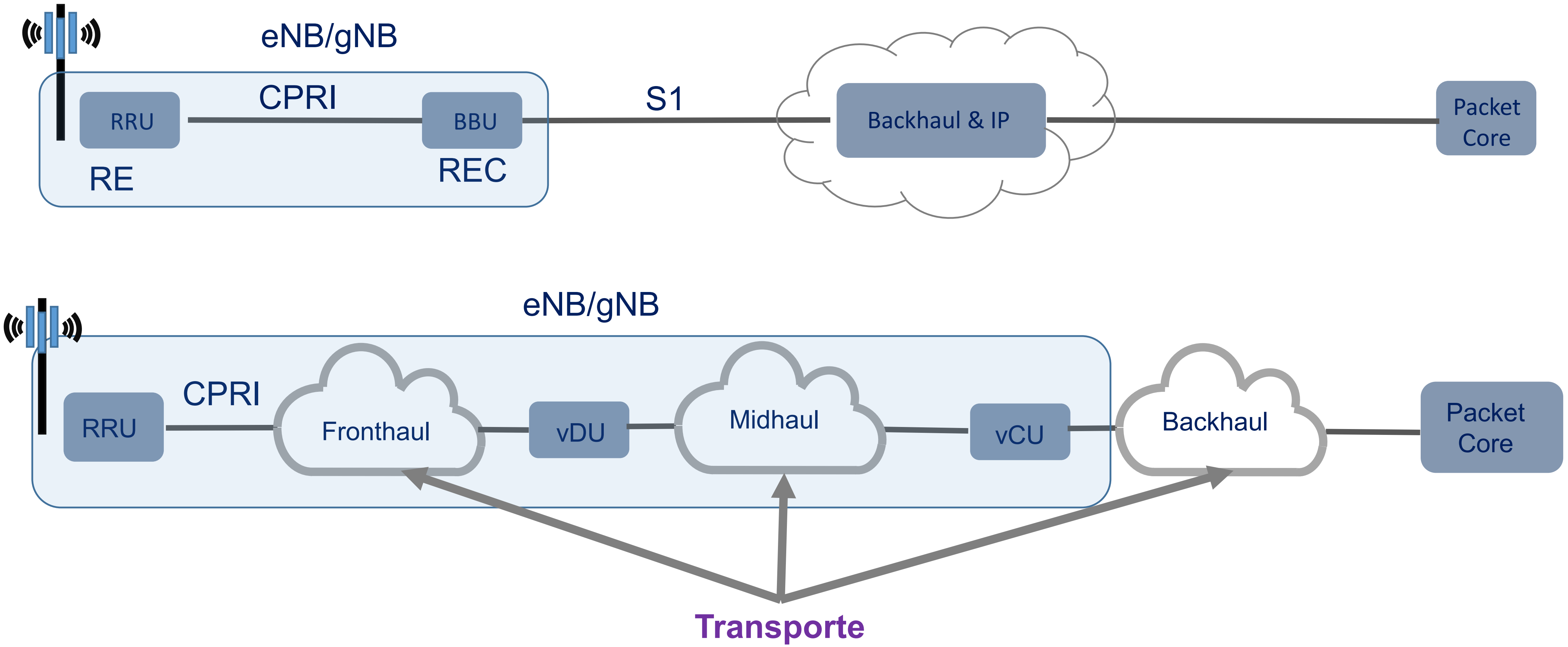
CPRI

El REC contiene las funciones de radio del dominio de banda base digital, mientras que el RE contiene las funciones de radiofrecuencia analógicas. La división funcional entre ambas partes se realiza de tal manera que se puede definir una interfaz genérica basada en datos en fase y cuadratura (IQ).

En E-UTRA, el REC proporciona acceso al núcleo de paquetes evolucionado para el transporte del tráfico del plano de usuario y del plano de control a través de la interfaz S1, mientras que el RE sirve como interfaz aérea para el equipo del usuario.



CASOS DE DESAGREGACIÓN



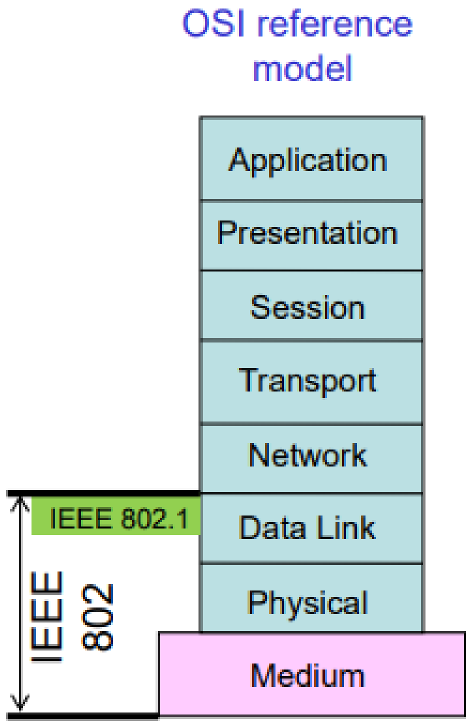
Discutir TSN!! Qué parte de la red debe cumplir con este requisito?

TSN (Time Sensitive Networks)

Revisar concepto y standares IEEE

Fuente de consulta: IEEE
https://1.ieee802.org/tsn/

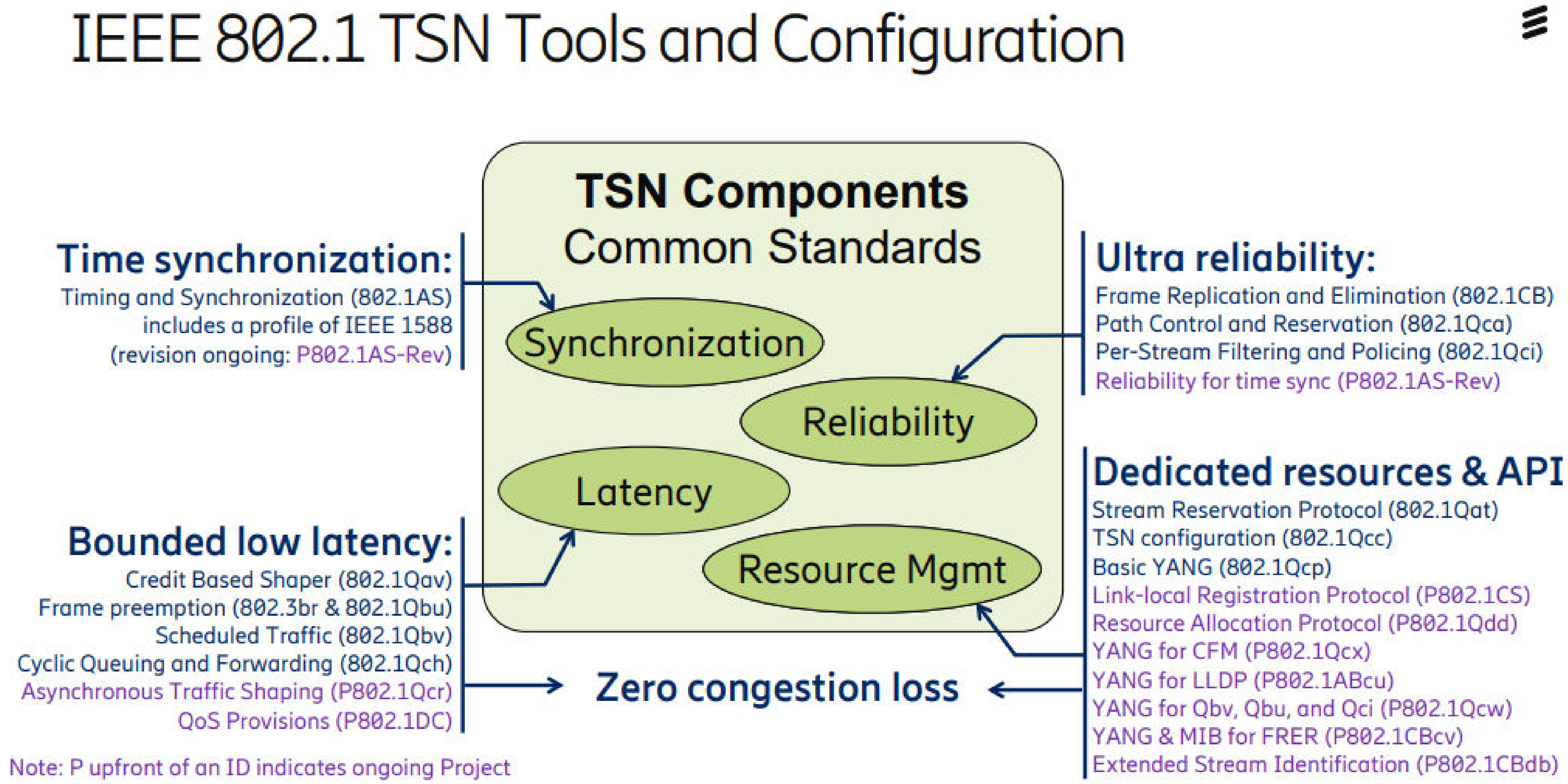
IEEE 802 LAN/MAN Standards Committee (aka IEEE 802 or LMSC)



- Develop LAN and MAN standards
- Mainly for link and physical layers of the network stack
- In operation since March 1980

Fuente: IEEE & Ericsson

TSN (Time Sensitive Networks)



Fuente: IEEE & Ericsson

TSN (Time Sensitive Networks)

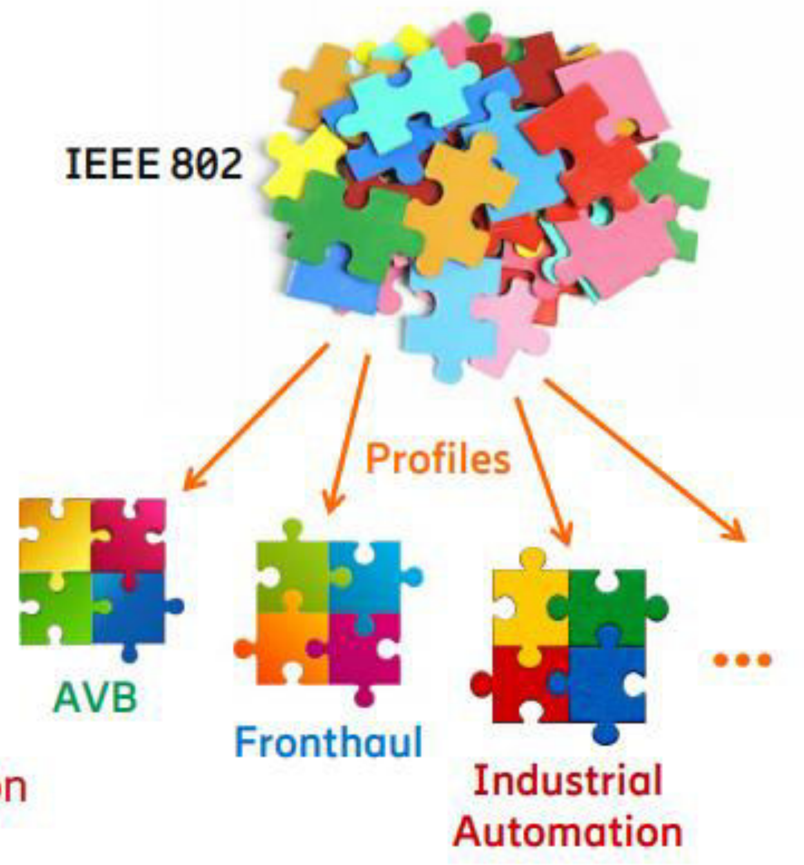
IEEE 802.1 Working Group

- Standards and recommended practices in the following areas:
  - 802 LAN/MAN architecture
  - Internetworking among 802 LANs, MANs and other wide area networks
  - 802 Security
  - 802 overall network management, and protocol layers above the MAC & LLC layers
- The 802.1 Working Group (WG) includes the following groups:
  - Time-Sensitive Networking (TSN) Task Group (TG)
    - Deterministic services through IEEE 802 networks
  - Security TG
    - Specifies functionality to support secure communication between devices (end stations and bridges) attached to IEEE 802 LANs
  - OmniRAN TG
    - Network reference model and functional description of IEEE 802 access networks
    - Multicast and local address assignment
  - Maintenance TG
    - Maintenance activities throughout the IEEE 802.1 WG
  - IEEE 802 "Network Enhancements for the Next Decade" Industry Connections Activity (NENDica)
    - Facilitates industry consensus towards proposals to initiate new standards development efforts
  - YANGsters
    - Common practice for YANG models supporting IEEE 802 protocols

Fuente: IEEE & Ericsson

TSN Profiles

- Wide breadth of choices in IEEE 802 standards
- A TSN Profile
  - Narrows the focus ➔ ease interoperability and deployment
  - Selects features, options, defaults, protocols, and procedures
  - Describes how to build a network for a particular use
  - Provides configuration guideline if needed
- TSN Profiles so far
  - Published TSN Profiles:
    - IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks
    - IEEE Std 802.1CM TSN for Fronthaul (for cellular networks)
  - Ongoing: IEC/IEEE 60802 TSN Profile for Industrial Automation
  - On the horizon:
    - P802.1DF TSN Profile for Service Provider Networks
    - P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications

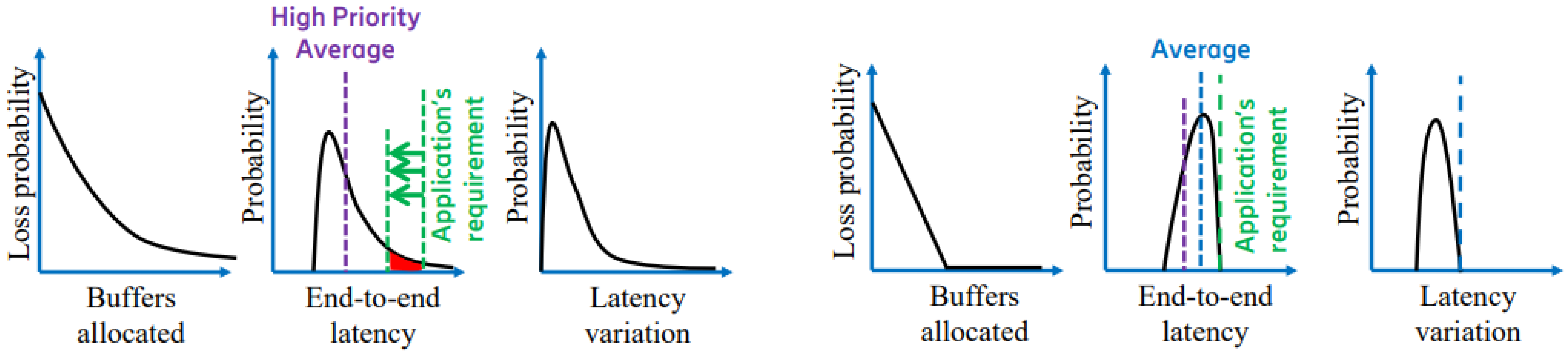


Fuente: IEEE & Ericsson

We Are Interested in Deterministic Service

— Traditional Service
  — Curves have long tail
  — Average latency is good
  — Lowering the latency means losing packets (or overprovisioning)

— Deterministic Service
  — Packet loss is at most due to equipment failure (zero congestion loss)
  — Bounded latency, no tails
  — The right packet at the right time



Fuente: IEEE & Ericsson

ASPECTOS DE RED QUE IMPACTAN EN EL TRANSPORTE

En términos de 5G RAN, de qué depende la red de Transporte?

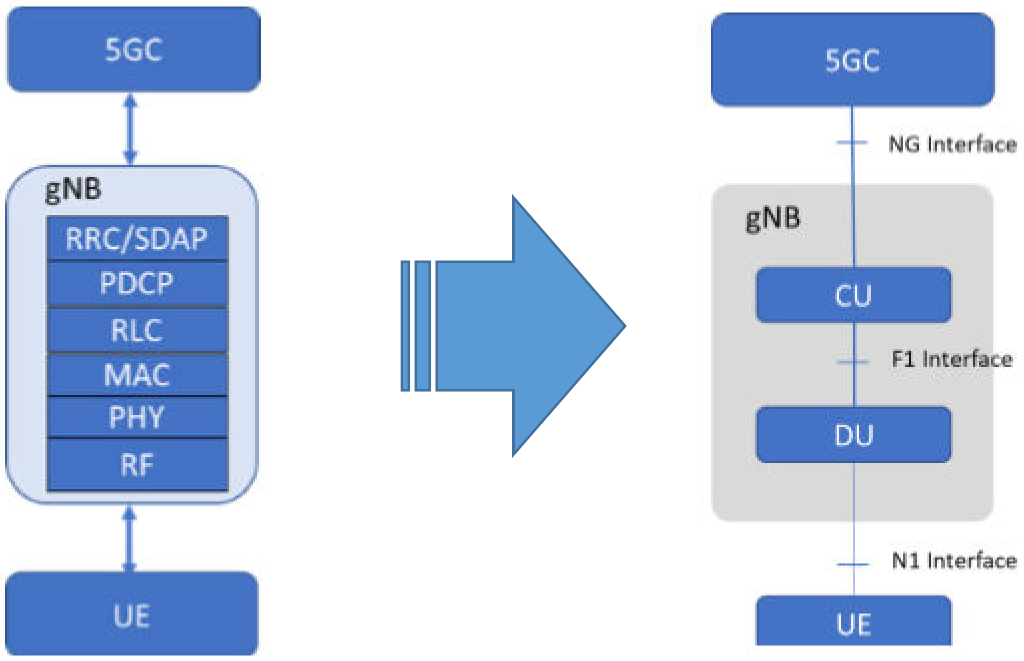
- Número de bandas de espectro
- Ancho de banda del canal por banda de espectro
- Número de capas MIMO
- Esquema de modulación máximo admitido
- Número de antenas de transmisión y recepción
- Casos de uso que deben ser compatibles con la red
- Algunos mas?.

La desagregación de las funciones de la red de acceso de radio (RAN) entre el sitio de la antena de radio y las ubicaciones centrales también juega un papel fundamental en los requisitos de transporte.

- Procesamiento de señales de radiofrecuencia (RF)
- Capa física (PHY)
- Control de acceso al medio (MAC)
- Control de radioenlace (RLC)
- Protocolo de convergencia de paquetes de datos (PDCP)
- Capas de control de recursos de radio (RRC).

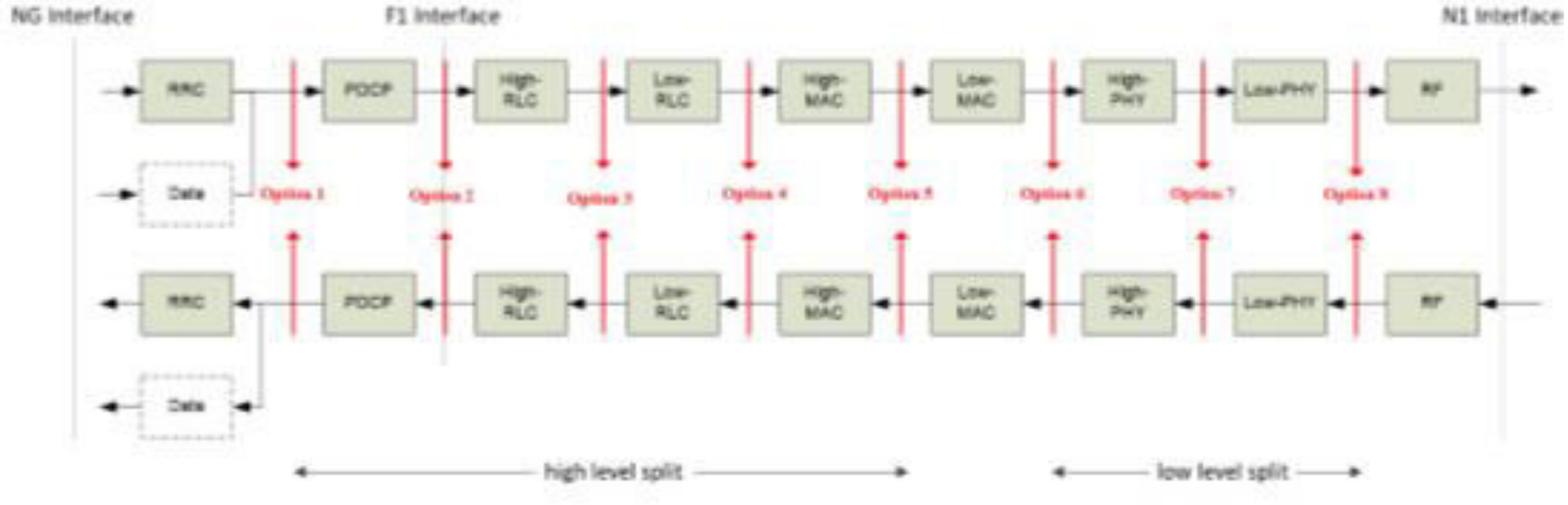
INCIATIVA DE 3GPP. CONCEPTO DE SPLIT DE RAN

3GPP definió una arquitectura RAN de próxima generación (NG-RAN) donde la funcionalidad de la estación base 5G NR (gNB) se divide en dos unidades lógicas: una unidad central (CU) y una unidad distribuida. (DU). En el modelo 3GPP, la CU está conectada al núcleo 5G (5GC) a través de la interfaz NG y la CU está conectada a la DU a través de la interfaz F1, como se muestra a continuación en la Figura 3.



Algunas funciones son Real-Time
Otras no.

INCIATIVA DE 3GPP. DISTINTOS SPLITs DE RAN

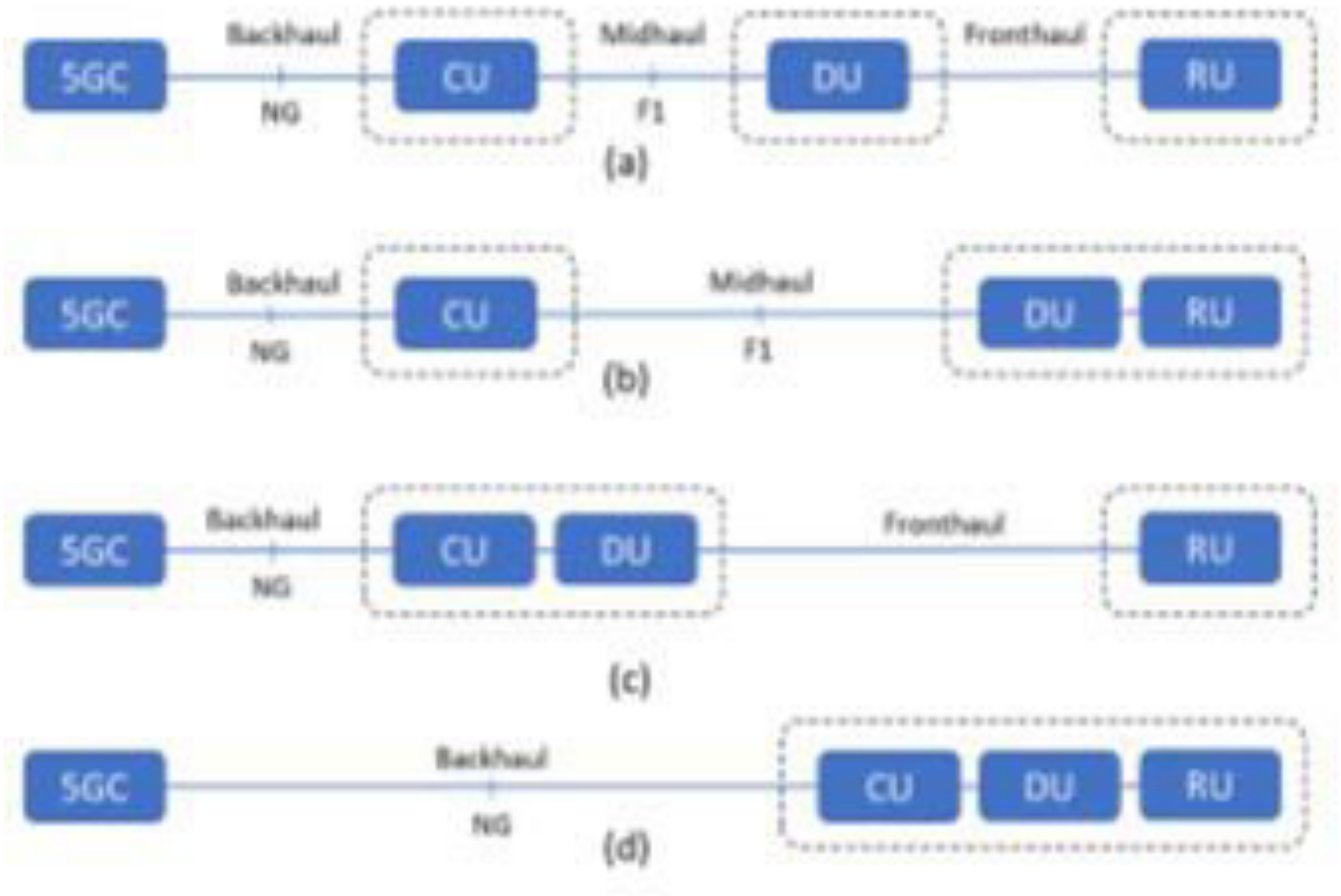


- Las señales de radio en NR constituyen una "cadena de servicios“.
- Se definen interfaces entre funciones, para lograr la desagregación.
- Las funciones que necesitan procesamiento en tiempo real se agrupan dentro de la DU, las que no, en la CU.
- A mayor centralización mayores requerimientos en general.

Split óptimo: topología de red, disponibilidad de fibra, cantidad de usuarios, volumen de servicio, etc

INCIATIVA DE ITU-T. DISTINTOS SPLITs DE RAN

La ITU-T, adoptó una arquitectura de transporte algo diferente para 5G, con tres elementos lógicos: CU, DU, y RU.

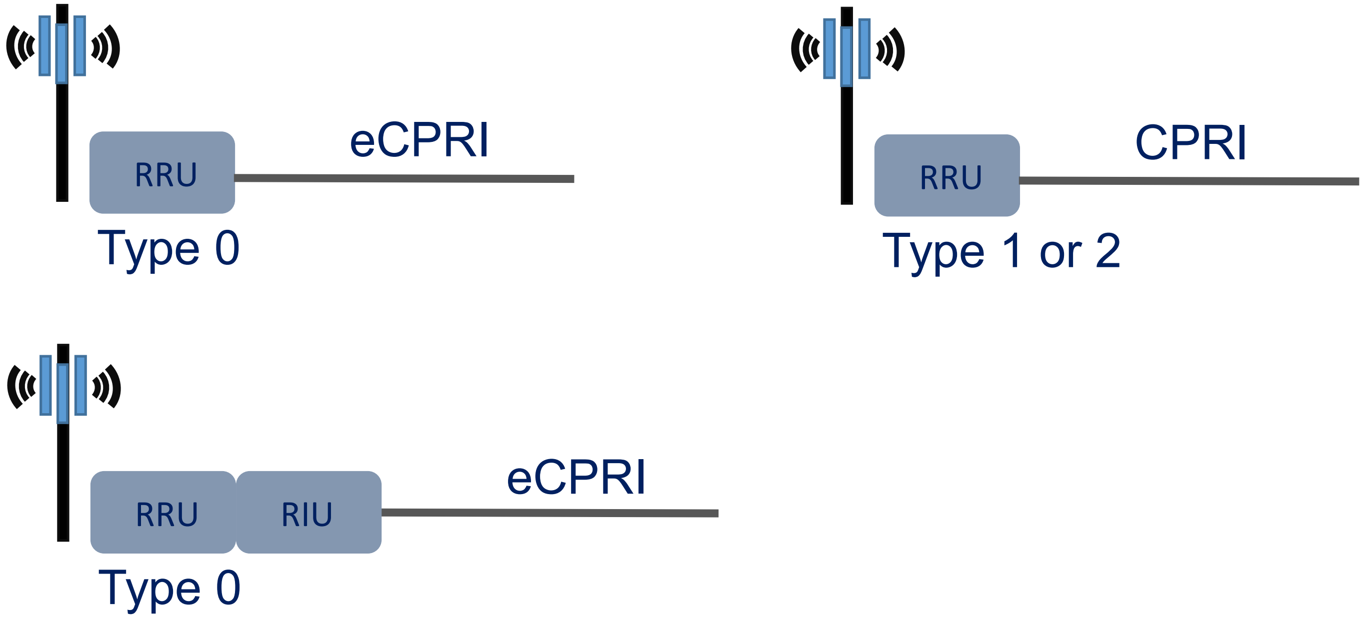


Fronthaul:
CPRI Vs eCPRI
CPRI: split 8 (RRH y BBU).
RRH: RU con una división funcional de Opción 8 (es decir, RF / PHY bajo)
BBU: DU y CU.
CPRI: para transportar muestras digitalizadas en el dominio del tiempo de la señal de banda base entre RRH y BBU

Analizar cada Split. xhaul

LA EVOLUCIÓN A eCPRI

La “CPRI cooperation”, lanzó una nueva versión de la especificación eCPRI (2.0): introduciendo una función de interfuncionamiento a la RU y DU existentes, de modo que CPRI y eCPRI puedan interfuncionar en la red. Un tipo de interfuncionamiento 0 es un dispositivo ubicado entre la red de transporte eCPRI y una o varias unidades de radio, mientras que los dispositivos de tipo 1 y 2 de función de interfuncionamiento se ubican entre los nodos CPRI y la red de transporte.



EL APORTE DE IEEE

Al mismo tiempo, el Instituto de Ingenieros Eléctricos y Electrónicos (IEEE) comenzó a trabajar en una Interfaz Fronthaul de Próxima Generación (NGFI).
Hay dos trabajos:

- IEEE 1914.1 cubre los estándares para redes de transporte fronthaul basadas en paquetes.
- IEEE 1914.3 que se encarga de la encapsulación y asignaciones **de Radio sobre Ethernet (RoE)** que direccionan las divisiones DU / CU en los splits 7.1 / 7.2 y 8.

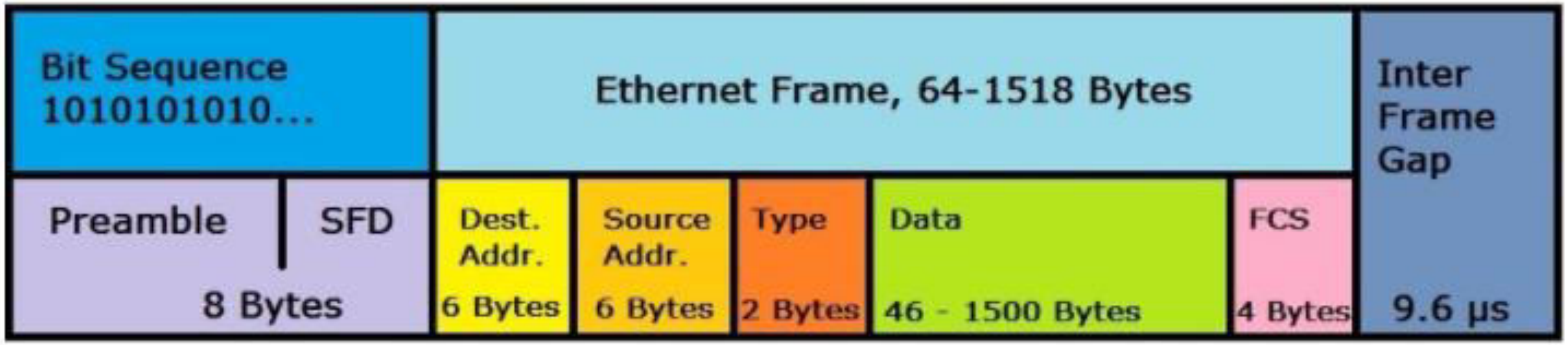
The traditional MFH network is being split into two key components called NGFI-I and NGFI-II, referenced in general as the xHaul; ***NGFI-I*** is the section between the RU and DU, while ***NGFI-II*** is the section between the DU and CU.

Los operadores que instalan nueva tecnología NR colocada en sitios LTE existentes están lidiando con el desafío de transportar CPRI y eCPRI hasta que todo el tráfico en el sitio celular sea eCPRI, momento en el cual las redes de conmutación de paquetes se pueden usar en la capa de transporte utilizando nuevos protocolos como Time Sensitive Networking. (IEEE 802.1CM) desarrollado para ofrecer baja latencia y sincronización precisa para el tráfico de fronthaul.

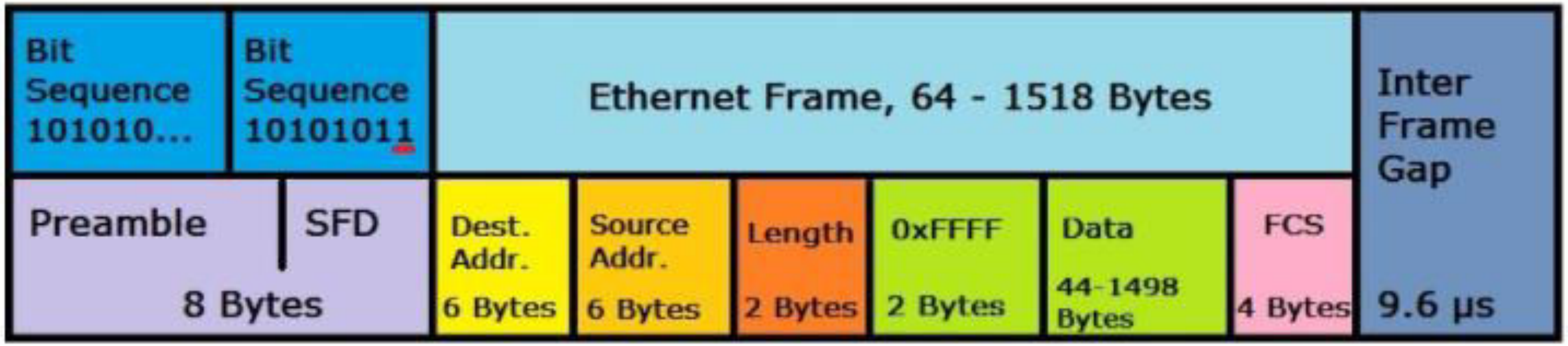
Discutir mapeos entidades duales

RoE Vs eCPRI

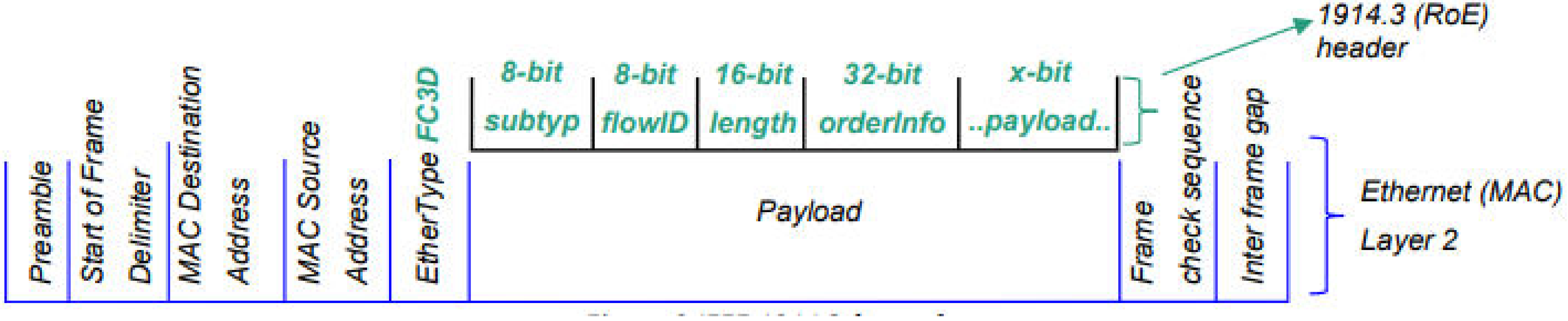
Eth II

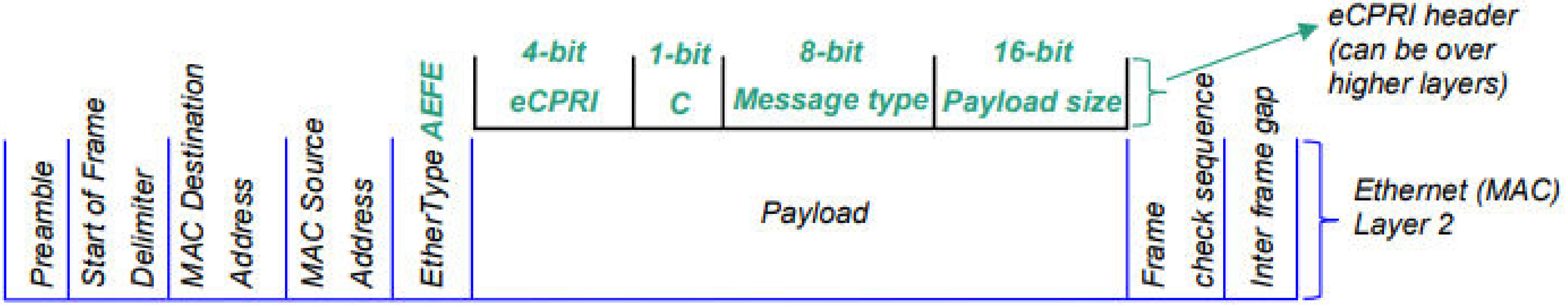


Eth 802.3 raw



RoE Vs eCPRI

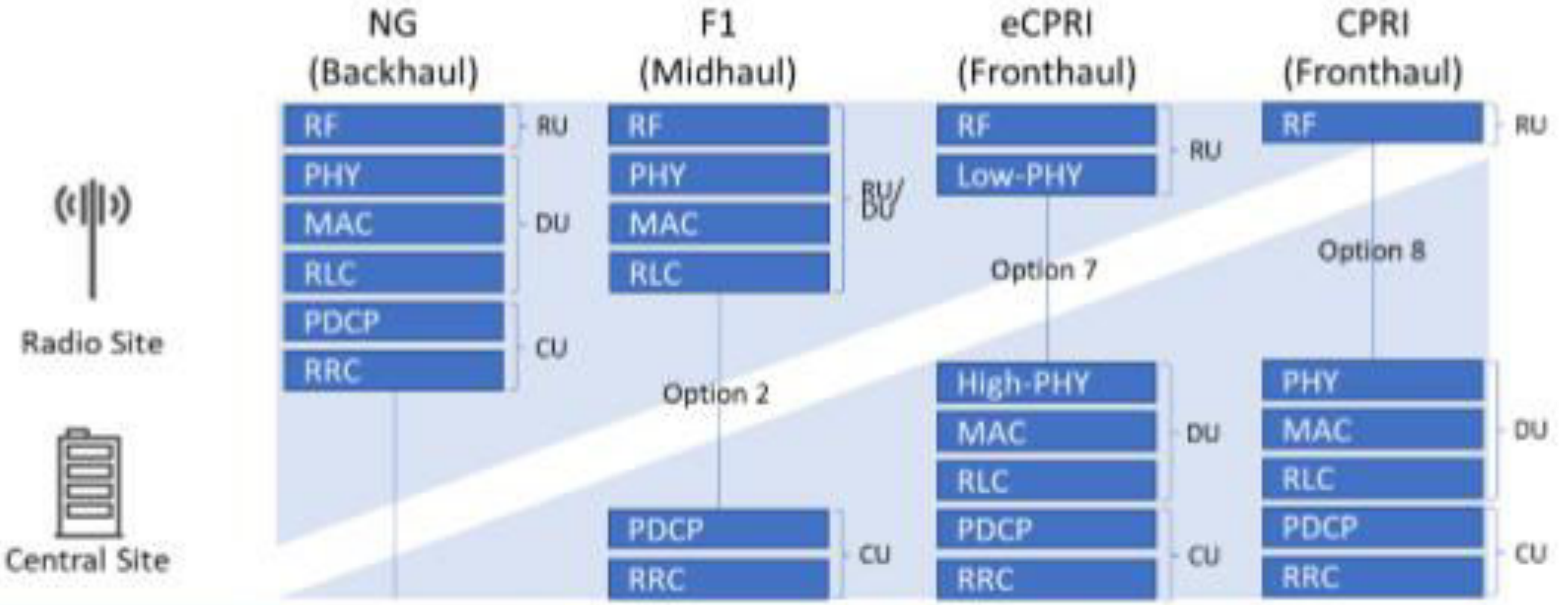




Fuente Anritsu envision : ensure

RELACIÓN ENTRE SPLITS Y REQUERIMIENTOS DE TRANSPORTE

Requisitos de latencia y velocidad de datos y limitaciones de distancia para las interfaces NG, F1, eCPRI y CPRI.
Ejemplo basado en un sitio de radio con 3 sectores, ancho de banda de canal de 100 MHz, 64 cadenas de transmisión / recepción, 256 QAM, 16 capas MIMO y MIMO multiusuario (MU-MIMO).



	NG	F1	eCPRI	CPRI
Data Rate	10 Gbps	10 Gbps	100 Gbps	1 Tbps
Latency	< 10 ms	< 5 ms	< 200 µs	< 100 µs
Distance	200 – 500 km	100 – 400 km	< 20 km	< 10 km

Fuente: NOKIA

EEE

OPEN RAN ALIANCE

La Alianza O-RAN anunció en junio de 2018 que lideraría los esfuerzos hacia una RAN abierta con interfaces interoperables y virtualización de RAN. La O-RAN Alliance tiene 9 grupos de trabajo que analizan muchos temas entre los que se puede citar, los protocolos L2-L3 RAN para la división de capa alta y las opciones L1 (por ejemplo, eCPRI e IEEE1914) para la división de capa baja.
O-RAN también introdujo una nueva arquitectura para el split funcional 7.2. Se especificaron dos categorías: Categoría A y Categoría B. La principal diferencia entre las dos es la ubicación de las funciones de precodificación para el enlace descendente. Los dispositivos de categoría A no tienen funciones de precodificación, mientras que los dispositivos de categoría B incluyen funciones de precodificación.

Precodificación (“precoding”)
Precoding se refiere al control individual de las amplitudes y fases de las señales enviadas desde las diversas antenas disponibles. Precoding se suele aplicar en concurrencia con Beamforming para direccionar la energía a las zonas deseadas.

EL PROBLEMA DE LA CAPILARIDAD EN mmWAVE

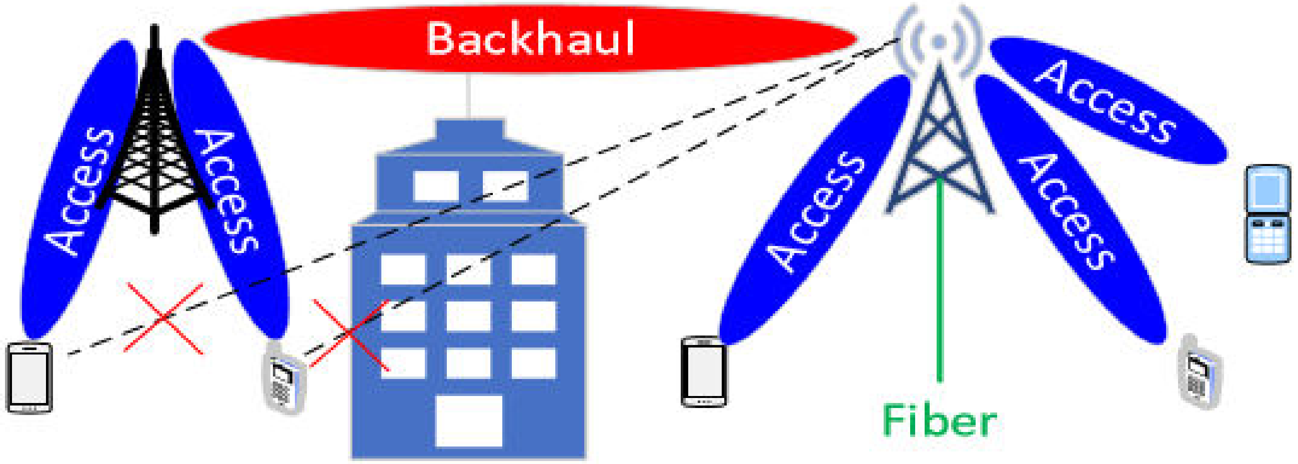
- Para lograr aumentar el ancho de banda, es preciso usar mmWaves
- Las mmWaves tienen alcance limitado
- Ello require llegar con transmission a una cantidad creciente de sitios
- A veces no se dispone de F.O en cada punto

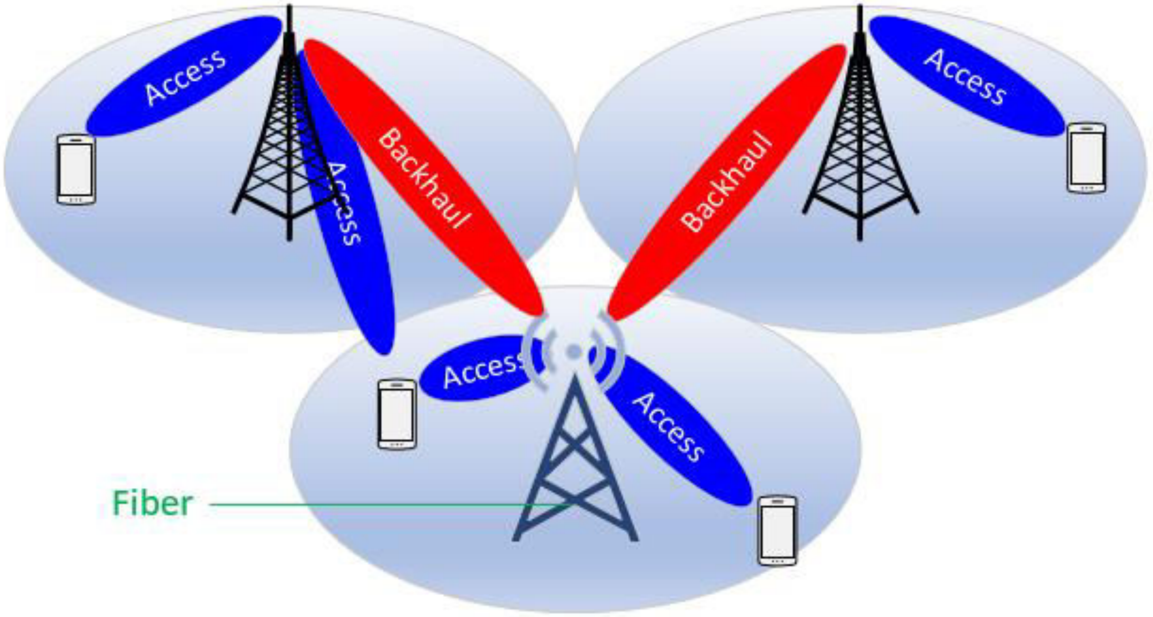
3GPP en el release 16, introduce el concepto de ***backhaul de acceso integrado (IAB)*** para permitir que la radio NR use parte del espectro RAN para la conectividad de backhaul. Como resultado, es posible utilizar NR para un enlace de backhaul inalámbrico desde ubicaciones centrales a sitios celulares distribuidos y entre sitios celulares.

IAB se puede utilizar en cualquier banda de frecuencia en la que pueda operar NR. Sin embargo, se anticipa que el espectro mmWave será el espectro más relevante para el enlace de backhaul. Además, el enlace de acceso puede operar en la misma banda de frecuencia que el enlace de backhaul (conocido como operación en banda) o usando una banda de frecuencia separada (operación fuera de banda).

Con el uso de microondas y espectro de mmWave, ie.: Banda E (70/80GHz), se puede transporter 10Gbps con baja latencia sobre un canal simple

IAB





Fuente: 5G Americas white paper

IAB

- Leverage existing technology: IAB technology leverages the already existing NR radio interface specification between device and network (NR Uu interface) for the backhaul radio link with modifications/ extensions.
- Low deployment and operational cost: An IAB node is a combination of a gNB and a UE that plays the role of an access node as well as a backhaul relay node simultaneously. By avoiding or delaying the need for dedicated backhaul, IAB reduces the deployment and operational cost significantly.
- Frequency band flexibility: Contrary to the IEEE 802.11ad/ay standard, an IAB network can operate on multiple bands available under the 3GPP 5G NR standard.
- Efficient spectrum usage: IAB allows for a more flexible spectrum usage where the spectrum can be efficiently utilized between access and backhaul, compared to the more static allocation for conventional wireless backhaul.
- In-band or out-of-band IAB: In case of in-band IAB, access and backhaul fully or partially overlap each other in frequency domain. While out-of-band IAB implies access and backhaul have no overlap in frequency domain.
- IAB is supported in stand-alone (SA) as well as non-stand-alone (NSA) architecture in 5G. UEs can transparently connect to the network via IAB.
- Flexible and spectrally efficient range extension: IAB supports backhaul topologies with multiple hops for extended range or to support deployments in convoluted urban canyons.

IAB

- Flexible quality of service (QoS) framework: IAB allows for fine-granular end-to-end QoS support of individual traffic flows across access and backhaul links as well as QoS-class-specific traffic prioritization as applied on Ethernet or IP transport networks.
- Robustness to backhaul link failure: Support for path redundancy in the wireless backhaul topology allows for robust operation in case of individual backhaul link failures, e.g., due to moving obstructions. The topological redundancy further enables dynamic load balancing across the backhaul links to optimize backhaul capacity to time-dependent traffic load.
- Optimized management of topology, routing and resource allocation: IAB follows the software-defined-networking paradigm where crucial management functions are centrally controlled. This enables optimization of the backhaul topology and the routing paths for traffic across this topology. Further, resource allocation for backhaul and access links are centrally managed which allows accounting for duplexing constraints across multiple hops and incorporating topology-wide inter-link interference mitigation. IAB further incorporates local decision-making processes to allow for flexible and fast response to highly dynamic resource demand and to reduce control-plane latency.

EJEMPLO REAL DE IAB

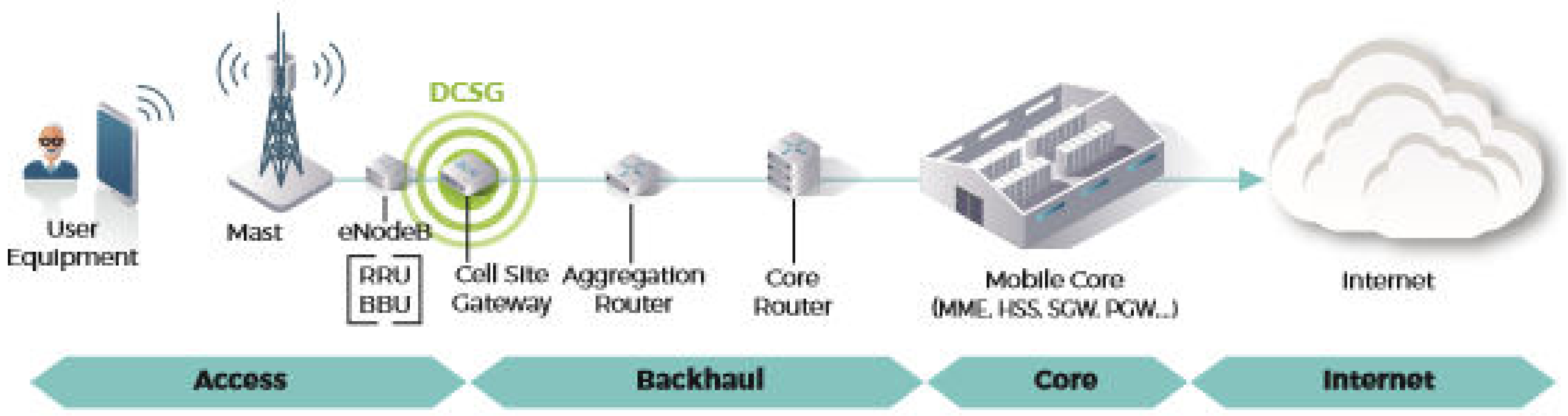
Topologia general

- Servicios dedicados de 100-1000 Mbps
- Distribución en 60Ghz
- Nodos PMP cada 200m aprox.
- Instalación de Nodos en luminarias y/o azoteas de casas
- 1 Equipo V1000 por cliente
- Se requiere LOS
- Estructura tipo Malla para minimizar puntos de falla
- Coberturas de 1-2 KM de diámetro.

Fuente: CnWave

DCSG

El DCSC (Disaggregated Cell Site Gateway), es una familia de enrutadores de agregación utilizado como punto de conexión del sitio a la red de transporte.
Hay ejemplos de DCSC, ciertos modelos "caja blanca" basados en una arquitectura abierta y desagregada para las infraestructuras móviles 2G / 3G / 4G y 5G existentes.

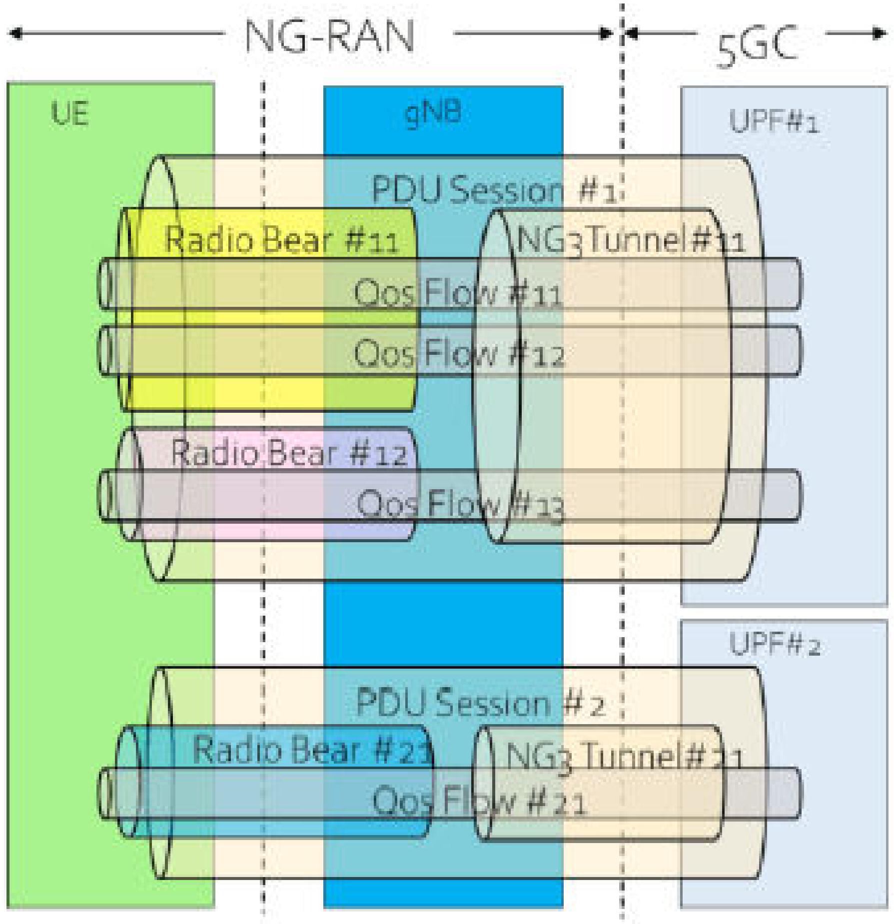


CALIDAD DE SERVICIO

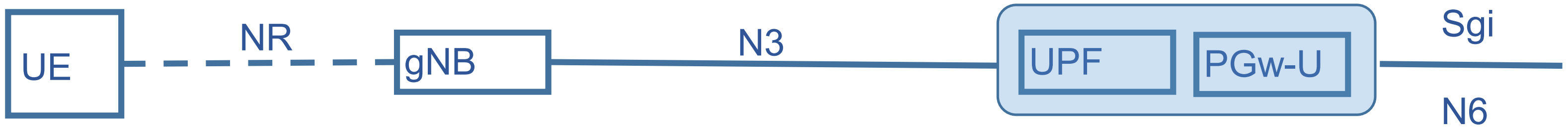
QoS en 4G: Ver documento específico

- ARP. PCI /PVI
- QCI GBR / NGBR
- MBR / AMBR
- EPS BEARERS /APN
- DSCP

CALIDAD DE SERVICIO en 5G



- PDU
- Radio Bearer
- NG3 Tunnel
- QoS Flow

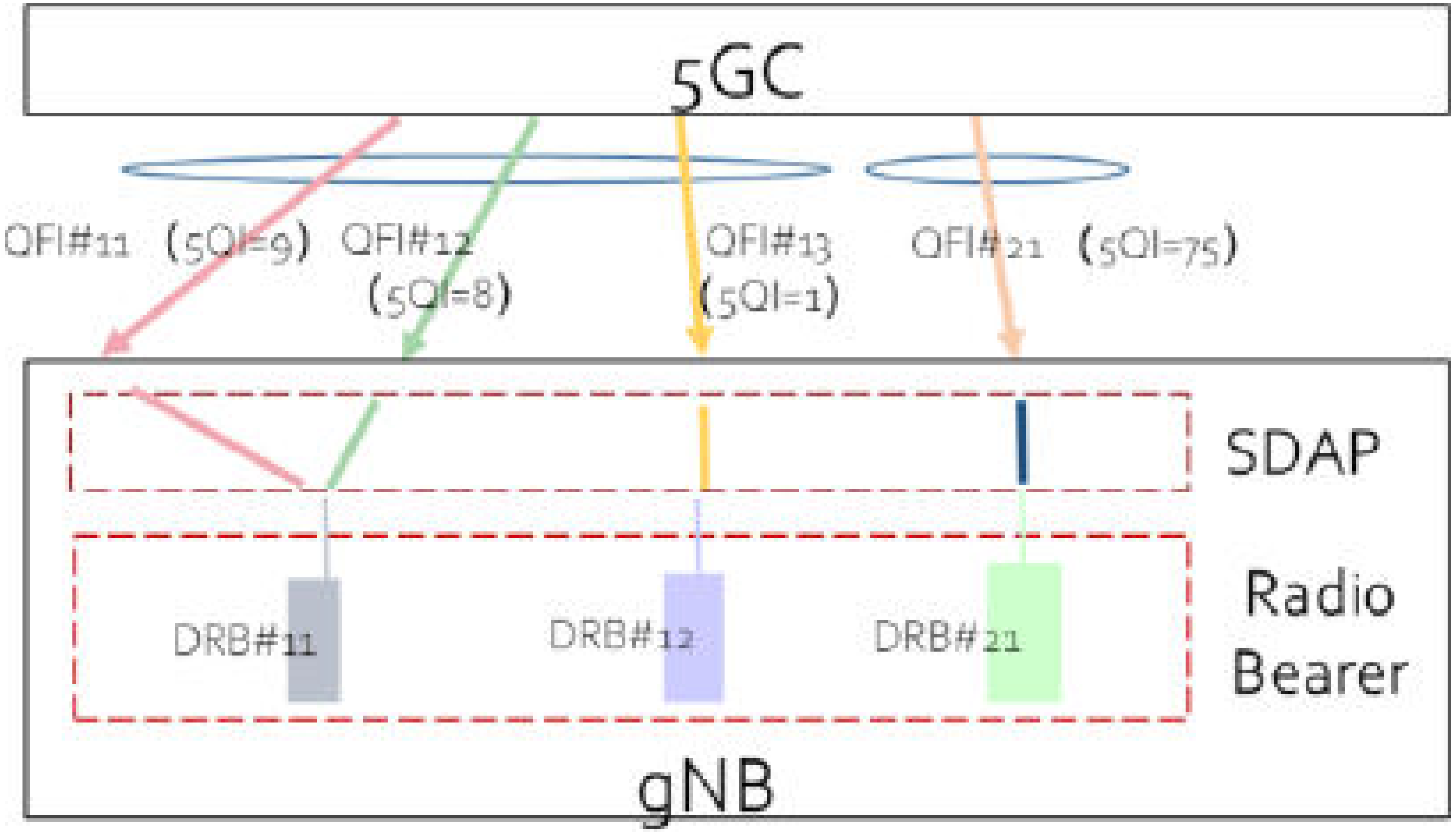


CALIDAD DE SERVICIO en 5G

La gestión de la calidad de servicio en 5G es más compleja que el simple mapeo de QoS de la bearer LTE EPS.

El modelo 5G QoS se basa en el flujo de QoS. El flujo de QoS es la mejor granularidad para diferenciar las distintas QoS en la sesión de la PDU y se identifica de forma única por el ID de flujo de QoS (QFI), que permite adaptarse a varios servicios.
El Core (5GC) mapea el paquete de servicio al QoSFlow, y el NG RAN mapea el QoSFlow al DRB en la interfaz aérea. para asegurar la calidad del servicio.
El 5GC establece una o más sesiones de PDU para cada UE. Se pueden establecer uno o más QoSflows en la sesión de la PDU.
En el mismo cuadro de diálogo de PDU, NG-RAN establece diferentes DRB para QoSflows con diferentes requisitos o mapea múltiples QoSflows con los mismos requireminetos de QoS a la misma DRB.

CALIDAD DE SERVICIO en 5G



- The 5G QoS architecture applies only to the SA networking scenario.

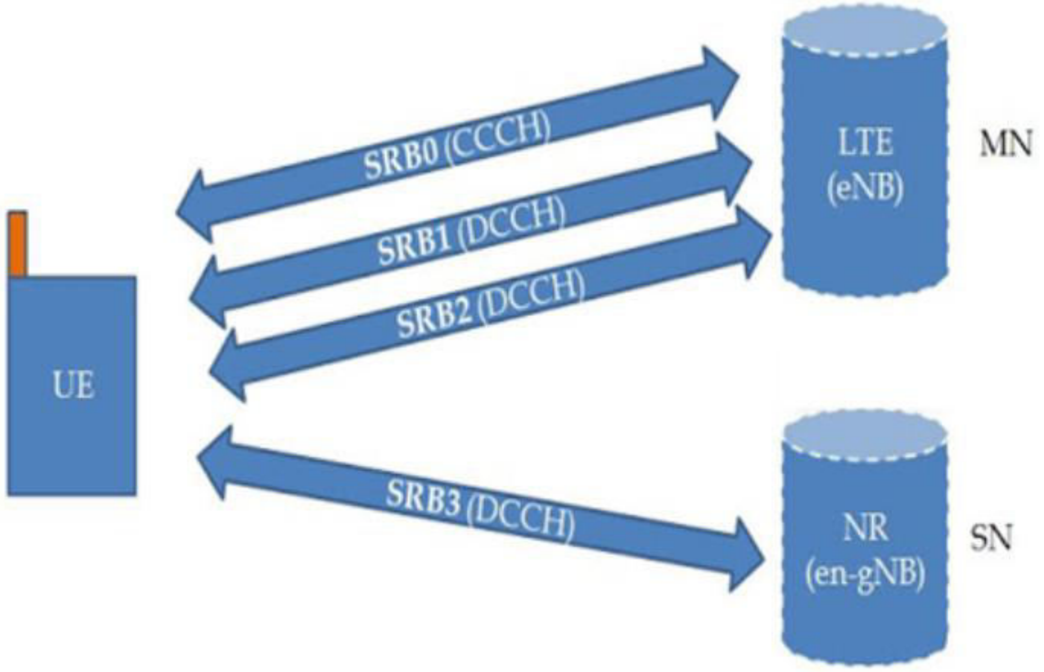
- The QoS object of 5G is PDU Session/QoSFlow, and that of 4G is E-RAB.

- The 5G uses the ***QoS Flow*** granularity for QoS control. The 4G uses the ***EPS Bearer*** for QoS control.

SIGNALLING RADIO BEARERS

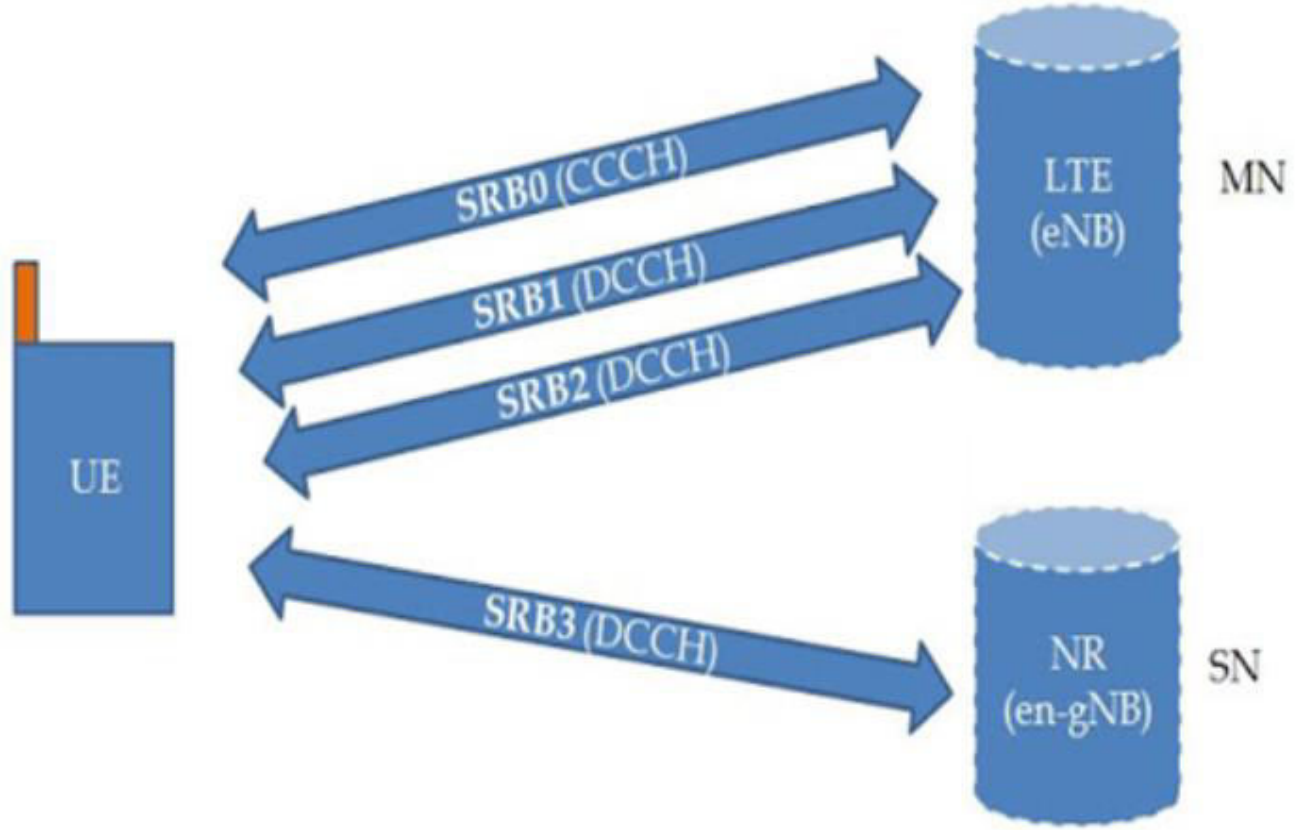
•SRB stands for Signaling Radio Bearer. "Signalling Radio Bearers" (SRBs) are defined as Radio Bearers (RBs) that are used only for the transmission of **RRC** and messages. As defined per 3GPP specification TS38.331, there are four different types of SRB in 5G New Radio (NR) defined as follows.

- **SRB 0** is for RRC messages using the *CCCH* logical channel;
- **SRB1** is for RRC messages as well as for *NAS* messages prior to the establishment of SRB2, all using *DCCH* logical channel;
- **SRB2** is for *NAS* messages, all using *DCCH* logical channel. SRB2 has a lower-priority than SRB1
- **SRB3** is for specific RRC messages when UE is in *EN-DC*, all using *DCCH* logical channel.



•In comparison to 4G, NR has one more SRB called SRB3. In case of EN-DC, SRB3 may be configured for the transfer of some NR RRC messages between UE and gNB via the NR radio interface.

SIGNALLING RADIO BEARERS



•**Advantages of SRB 3:**
•SRB3 is optional and provides a direct SRB between the Secondary RAN Node and the device, If SRB3 is not configured by network then LTE RRC (via X2 interface) are able to pass the NR RRC messages between the UE and en-gNB and it's utilizing SRB1.

- The advantages of introducing new SRB3:
  - Direct RRC communication between UE and SgNB
  - Enable the 5G node to make intra-SgNB handover decisions.
  - Reduced latency of the RRC signalling between UE and SgNB
  - Direct Measurement Reports sent to SgNB which leads to faster and direct reports for HO purposes.

SINCRONISMO

SINCRONISMO

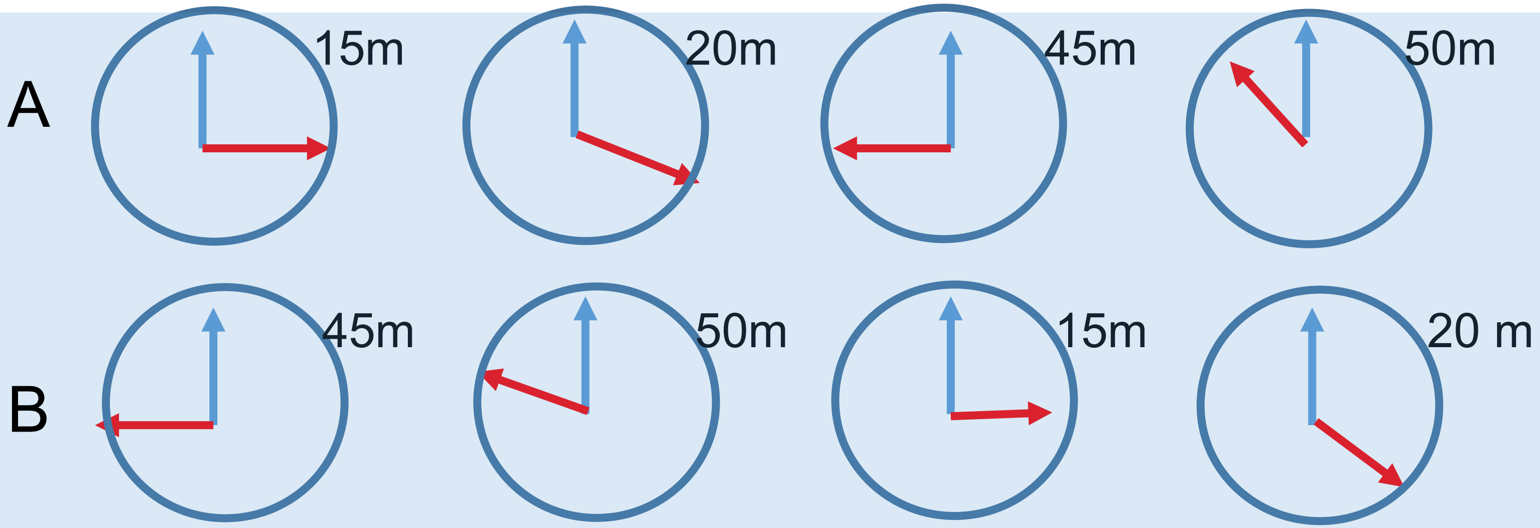
En todas las comunicaciones digitales se require mantener sincronismo entre los nodos/entidades que la componen.
En las redes móviles el sincronismo se vuelve crítico pues el UE se ve somentido a procedimientos de red como handover, fallback, etc, mecasnimos todos ellos en los que se produce una interrupción y reconexión a la red desde otro punto

Algunos ejemplos:
- En LTE y 5G, un terminal en medio de una session, hace un handover.
- Un terminal utiliza servicios de Carrier Aggregation
- Un terminal usa Dual Connnectivity

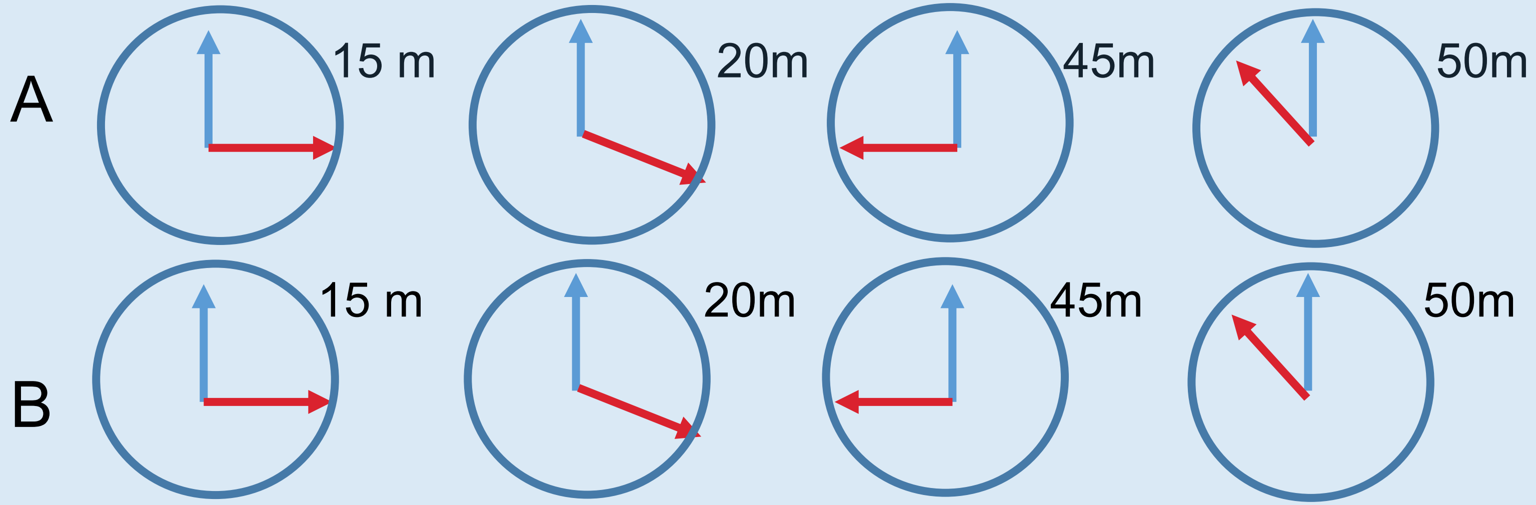
La sincronización de red es responsable de la distribución de los relojes , y permite a los relojes operar a la misma frecuencia en diferentes nodos. Hay que tener en cuenta que el reloj en este contexto no se ocupa de la hora del día , sino sólo de la frecuencia. La red de sincronización proporciona señales de referencia de temporización a redes de tráfico de telecomunicaciones . El objetivo de las redes de tráfico es transportar información sin perturbaciones ni distorsión. Una sincronización pobre a menudo conduce a la pérdida de información.

Discutir tipos de sincronismo

SINCRONISMO DE FRECUENCIA Y SNCRONISMO DE FASE



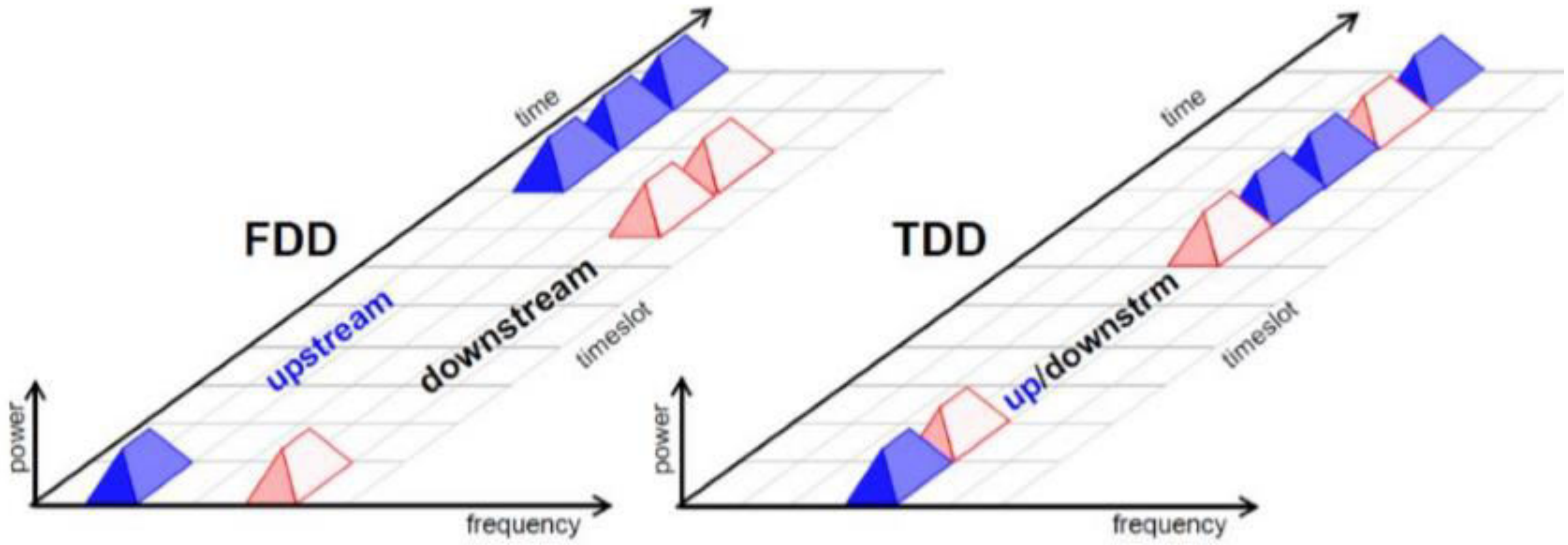
Sincronización de Frecuencia
El reloj A y el reloj B marcan una hora diferente pero mantienen una diferencia horaria constante



Sincronización de Fase
El reloj A y el reloj B siempre marcan la misma hora

Disponer sincronismo de frecuencia implica disponer de sincronismo de fase?

SINCRONISMO DE FRECUENCIA Y SNCRONISMO DE FASE



Como se ha visto, se dispone básicamente de dos sistemas de duplexación, TDD y FDD.
En el caso se TDD, desde el punto de vista del sincronismo, las exigencias son mayores que en FDD ya que se require una referencia absoluta de tiempo y fase para poder acceder a los intervalos de tiempo asignados a cada canal (UL y DL)

REQUERIMIENTOS DE SINCRONISMO DE FASE Y DE FRECUENCIA

Tecnologías de red móvil	Sincronismo de frecuencia	Sincronismo de fase/tiempo
GSM	●	
UMTS-FDD	●	
LTE-FDD	●	
UMTS-TDD	●	●
LTE-FDD con features avanzados	●	●
LTE-TDD	●	●
WiMAX	●	●
TD-SCDMA	●	●

PRC, por lo general es de cesio y genera referencia de frecuencia que es lo que se necesitaba en SDH.

PRTC, genera referencia de tiempo, suelen estar unidos a satélites, usan reloj de cesio y GPS. Osciloquartz solo usa solo GPS

Los relojes proporcionan pps, 10 MHz, 2MHz, syncE, PTP (frec) o PTP (tiempo), etc.
En PTP 8275.1, los mensajes van en tramas, en capa e2 multicast.
En PTP 8275.2, los mensajes van en IP.

¿Cómo serán las exigencias en 5G?

REQUERIMIENTOS DE SINCRONISMO DE FASE Y DE FRECUENCIA

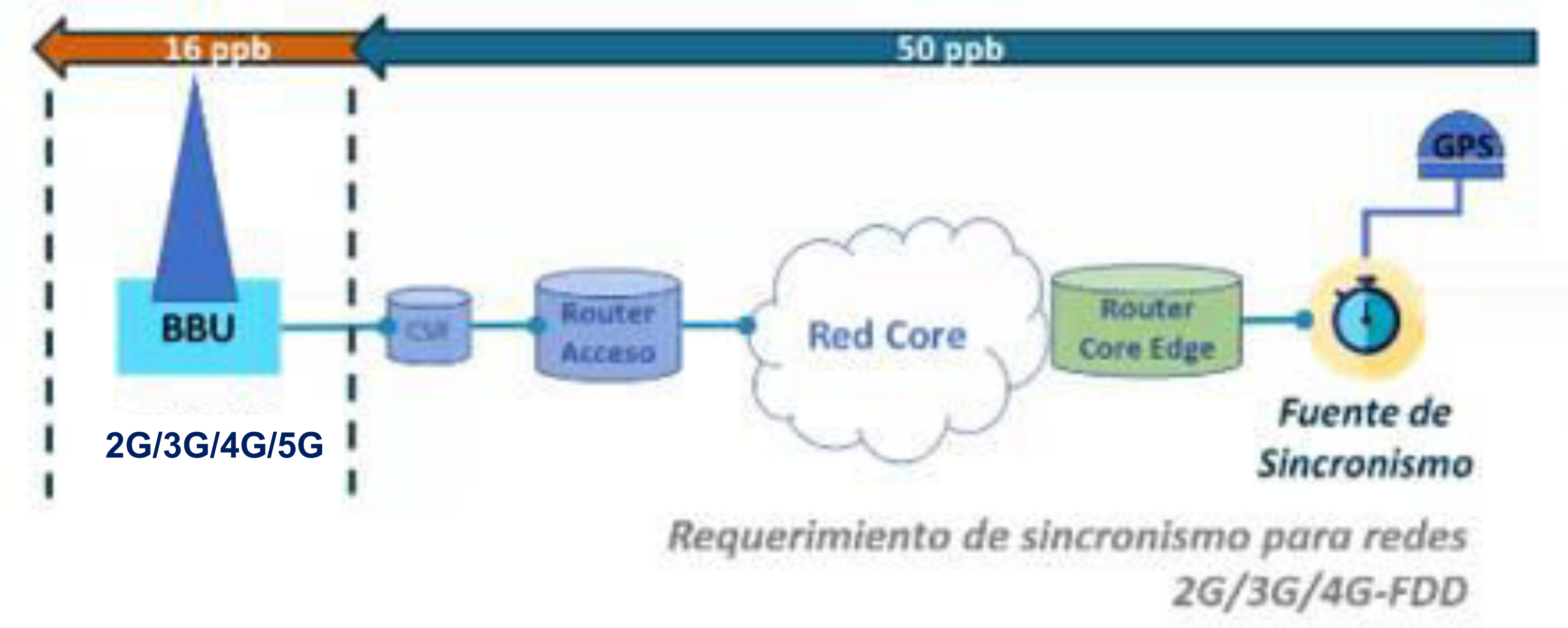
Tecnología de red móvil	Estabilidad de frecuencia red/aire	Fase	Nota
GSM, UMTS, WCDMA, LTE – FDD	16 ppb / 50 ppb	--	--
CDMA2000	16 ppb / 50 ppb	± 3 μs to ± 10 μs	--
LTE – TDD	16 ppb / 50 ppb	± 1.5 μs	≤ 3 km cell radius
		± 5 μs	> 3 km cell radius
LTE MBMS (LTE-FDD & LTE-TDD)	16 ppb / 50 ppb	± 10 μs	inter-cell time difference
LTE- Advanced	16 ppb / 50 ppb	± 1.5 μs to ± 5 μs	In discussion by members of the 3GPP

Las tecnologías móviles 2G, 3G y LTE-FDD requieren solamente sincronización de **frecuencia** con una precisión dentro de 50 ppb (parts per billion) en la interfaz de red. Para reunir este requerimiento, se especifica 16 ppb en la interfaz de la radio base a la red de backhaul.

LTE-TDD y los servicios de LTE Advanced tienen el mismo requerimiento de **frecuencia** que las generaciones anteriores, pero también especifica requerimientos para **fase** y **tiempo**.

En 5G, aparecen bandas TDD (p ej las del G1), lo cual torna mas crítico el sincronismo.
La sincronización de **fase** es mandatoria.

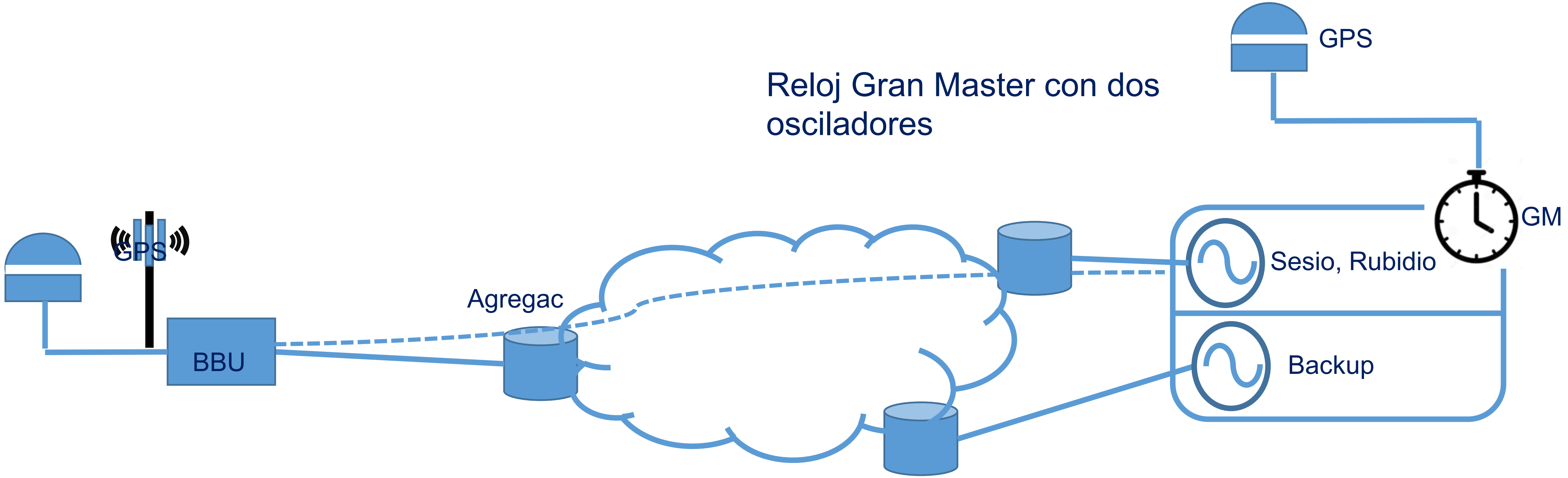
SINCRONISMO: FUENTES Y DISTRIBUCIÓN



Fuentes:
- GPS
- Local (Sesio, Rubidio, cuarzo)

Distribución:
- Hay casos en los que no todos los nodos disponen de Fuente local.
- Hay otros casos en los que además de la Fuente local, se require otra Fuente.
- Protocolo Cliente- Servidor IEEE 1588v2

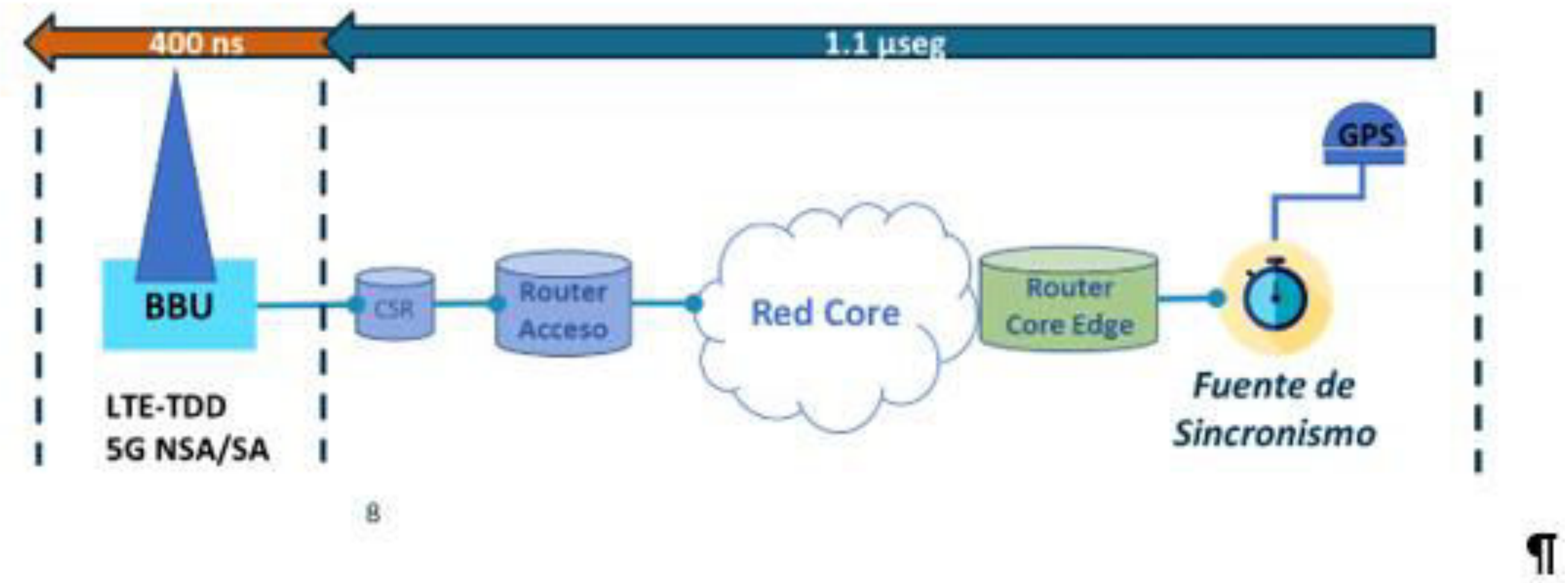
SINCRONISMO. FUENTES Y DISTRIBUCIÓN



En redes 3G y 4G (excluyendo ciertos servicios mejorados), se require sincronismo de frecuencia con **+-50 ppb** en la red y **+-16 ppb** en la interfaz de aire

Sin embargo, en 5G, y en especial en sistemas TDD, ya se requiere sincronismo de fase con un error de tiempo no mayor a **1,5 microsegundos.**

SINCRONISMO. SISTEMAS TDD



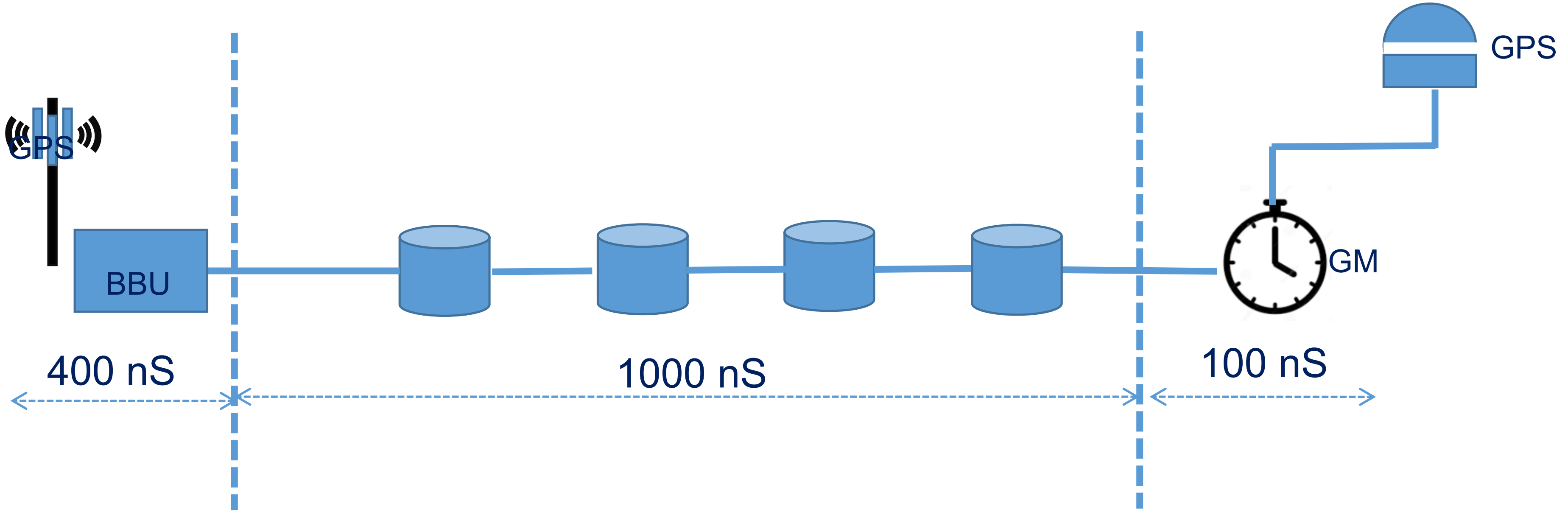
Se debe garantizar que el error de tiempo de toda la red, no supere el **1,5 microsegundo.**
Pensar un evento de red que requiera sincronismo de fase, y evaluar los tiempos de las ranuras.

Mantener acotado el error de tiempo permite eliminar tiempos de guarda

Desafiar el error de tiempo admitido de 1,5 microsegundos. Realmente alcanza?

SINCRONISMO. SISTEMAS TDD. ERROR DE TIEMPO

El Time Error es la diferencia entre el tiempo UTC reportado por una fuente de sincronismo y el reloj de referencia local. Es un parámetro fundamental en sistemas TDD (ITU-T G..8271.1)



Desafiar el error de tiempo admitido de 1,5 microsegundos. Realmente alcanza?

SINCRONISMO. SISTEMAS TDD. ASIMETRÍAS

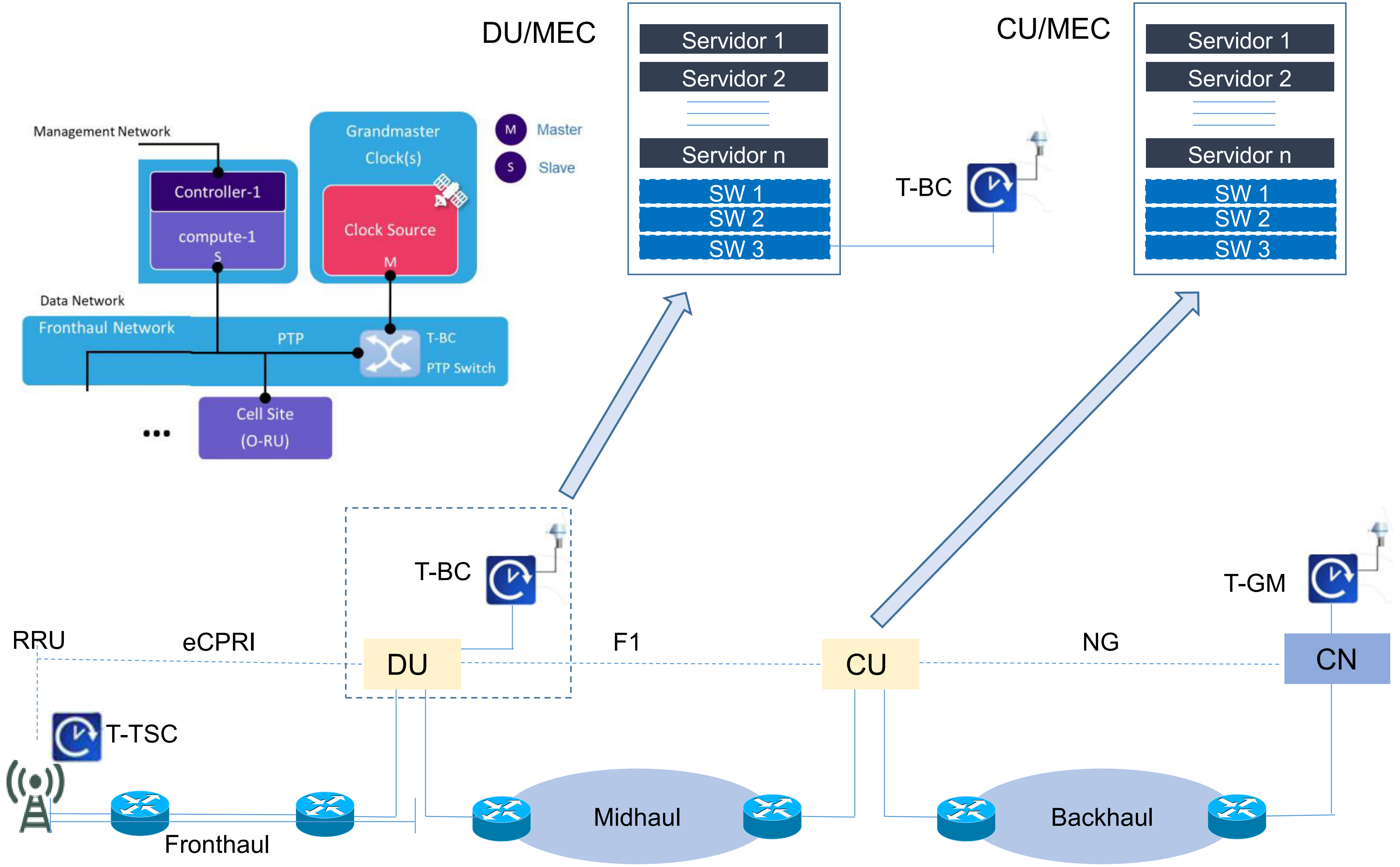
Asimetrías y Path Delay Variation

- El sincronismo en una red se va degradando tras el paso por cada equipo en red y por efectos no deterministas entre el reloj y el cliente, dichos efectos tienen su origen en en las asimetrías del Path de transmisión de sincronismo y el Packet Delay Variation (PDV):
  - ❑ Packet Delay Variation son las variaciones de latencia paquete a paquete.
  - ❑ Las asimetrías están referidas a las diferencias entre Downlink/uplink o efectos de ruido de fase.

- Las principales fuentes de PDV/Asimetría son:
  - *Variaciones en Router/switch*
    - ❑ Tránsito a través de un equipo LY2/LY3: Buffering, queuing y procesamiento de paquetes.
    - ❑ Variación de Payload: Se recomienda usar un frame idéntico en toda la red evitando Jumbo Frames para eliminar esta problemática.

  - *Asimetrías en el Network Path*
    - ❑ Diferencias entre el path Downlink/uplink (por ejemplo: respaldar un path principal de FO con uno de DWMD).
    - ❑ GnodeB fuera de fase generando interferencias.

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G



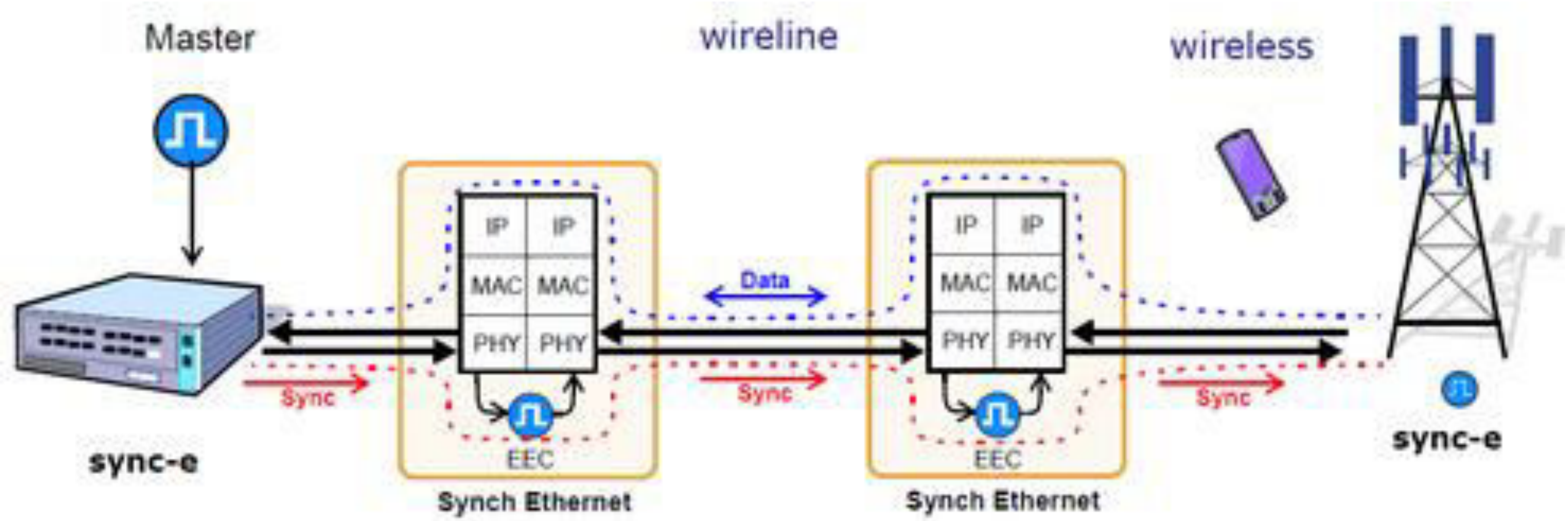
Es posible utilizar GPS en lugar de PTP?

CONSIDERACIONES GENERALES

1. Evitar usar *Network Elements* con elevado PDV y Time Error: Microondas y DWDM.
2. Evitar balanceos por flujo.
3. Priorizar por Ingeniería de tráfico el uplink de menor impato temporal entre HL4-HL3:
   - ❑ Fibra Oscura (1ª Prioridad).
   - ❑ DWDM (2ª Prioridad).
4. No utilizar Etherchannels para transportar sincronismo.
5. GMC con puertos de 10GE BiDi en HL3 y 1GE BiDi en HL4
6. Carga de la red Metro y acceso <80%.
7. Aplicar modelo de QoS E2E con el sincronismo en el mayor nivel de jerarquía (DSCP49).
8. PLR < 1%.
9. No utilizar Jumbo Frames en la ruta de transporte

SYNCE

Utiliza la señal de línea Ethernet para extraer señal de sincronismo.
Un nodo SyncE debe ser capaz de recibir, e interpreter la trama SyncE, enganchar la entrada con la salida, y generar una trama SyncE.
La señal SyncE se transmite sobre la capa física Ethernet .
Idealmente debería ser enganchada a un único reloj externo (GM Clock) .
Se aplica en redes móviles, tecnologías de acceso tales como Ethernet, PON, IPTV, VoIP, etc.



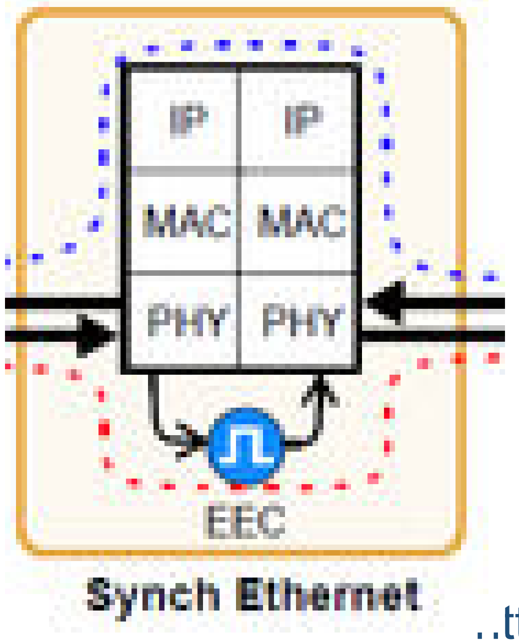
https://www.youtube.com/watch?v=XTEGeqJRDfs

SYNCE

A diferencia de las redes TDM, la familia Ethernet (e IP) no lleva información de sincronización de reloj.
Para cubrir ese aspecto, varias alternativas se han considerado, como PTP (ya visto), NTP, un protocolo creado por IETF (que no es apto para 5G), y SyncE que fue standarizado por la ITU-T en cooperación con IEEE y que junto con PTP constituyen una dupla interesante:

1. ITU-T Rec. G.8261 that defines aspects about the architecture and the wander performance of SyncE networks
2. ITU-T Rec. G.8262 that specifies Synchronous Ethernet clocks for SyncE
3. ITU-T Rec. G.8264 that describes the specification of Ethernet Synchronization Messaging Channel (ESMC)

La salida se "engancha" con la entrada, para propagar el clock.



La arquitectura SyncE require minimamente el reemplazo del clock interno de la placa Ethernet por un PLL para alimentar la salida física

..ttps://www.youtube.com/watch?v=XTEGeqJRDfs

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G O-RAN

5.5 Sync Architecture

Synchronization mechanisms and options are receiving significant attention in the industry.

Editor's Note: O-RAN Working Groups 4 and 5 are addressing some aspects of synchronization, and more discussion of Sync is expected in future versions of this document.

Version 2 of the Control, User and Synchronization (CUS) Plane Specification [7] discusses, in chapter 9.2.2, "Clock Model and Synchronization Topology", four topology configuration options Lower Layer Split Control Plane 1 – 4 (LLS-C1 – LLS-C4) that are required to support different O-RAN deployment scenarios. Configuration LLS-C3 is seen as the most likely initial option for deployment and is discussed below. This section will provide a summary of what is required to support the LLS-C3 synchronization topology from the cloud platform perspective.

Note that in chapter 6 "Deployment Scenarios and Implementation Considerations" of this document, we call the site which runs the O-vDU the "Edge Cloud", while the Control, User and Synchronization (CUS) Plane Specification [7] calls it the "Central Site". However, the meaning is the same.

5.5.1 Cloud Platform Time Synchronization Architecture

The Time Sync deployment architecture which is described below relies on usage of Precision Time Protocol (PTP) IEEE 1588-2008 (a.k.a. IEEE 1588 Version 2) to synchronize clocks throughout the Edge Cloud site.

For LLS-C3 in the CUS specification [7], vO-DU may act Telecom Slave Clock (T-TSC) and select the time source the same SyncE and PTP distribution from fronthaul as O-RU. For vO-DU, only the ITU-T G.8275.2 type T-TSC will be addressed; others are For Further Study.

5.5.1.1 Edge Cloud Site Level – LLS-C3 Synchronization Topology

This section outlines what the time synchronization architecture should be from the cloud platform perspective, and identifies requirements that the Cloud Platform and Edge Site need to support in order to support the O-RAN deployment scenarios that use the LLS-C3 synchronization topology described in CUS specification [7].

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G O-RAN

5.5.1.1.1 LLS-C3 Synchronization Topology Edge Site Time Synchronization Architecture

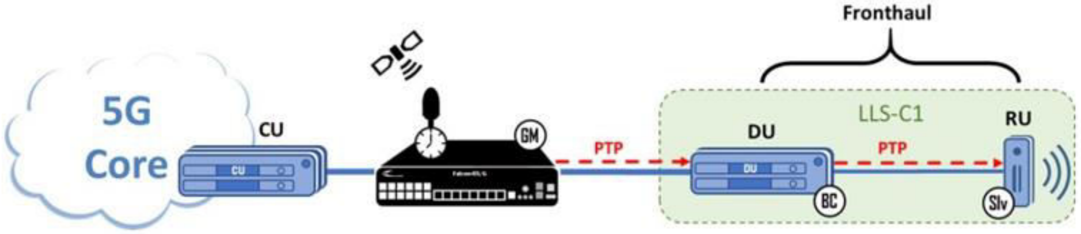
The deployment architecture at the Edge Cloud site level includes:

- Primary Reference Time Clock (PRTC)-traceable time source (i.e., Grandmaster Clocks):
  - External precision time source for the PTP networks, usually based on Global Navigation Satellite System/Global Positioning System (GNSS/GPS)
- Compute Nodes:
  - Compute Nodes synchronize their clocks to a Grandmaster Clock via the Fronthaul Network
- Controller Nodes:
  - Controller Nodes synchronize their clocks to the Network Time Protocol (NTP) via the Management Network

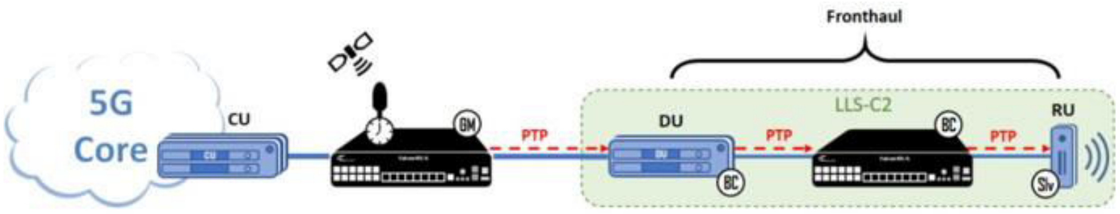
Figure 19 illustrates the relationship of these entities where the Controller functions are hosted on separate nodes from the Compute nodes. Figure 20 illustrates the relationships where each Compute node also includes the Controller functions (i.e., the hyper-converged case).

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G O-RAN

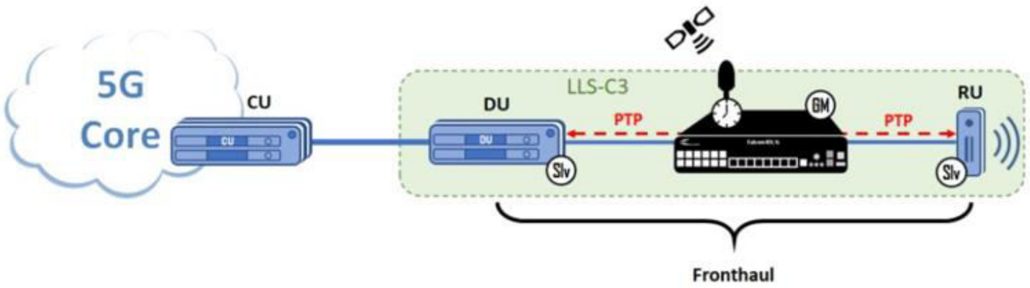
LLS C1



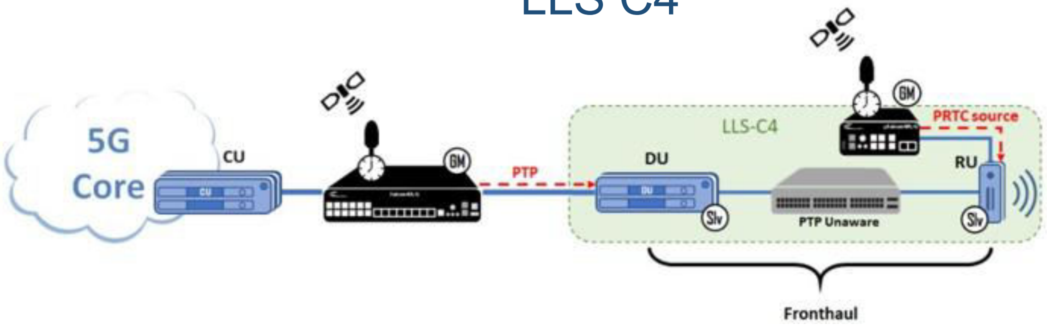
LLS C2



LLS C3



LLS C4



ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G O-RAN

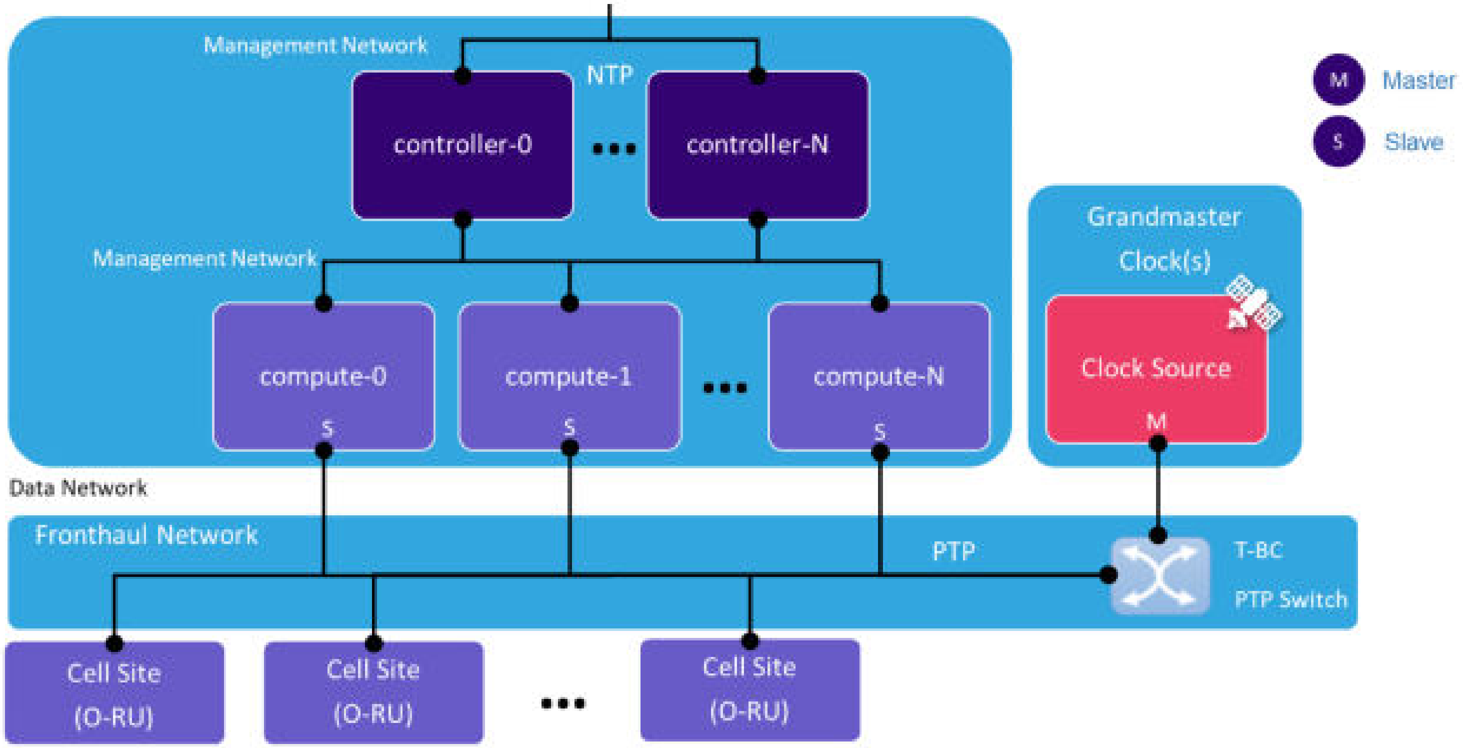


Figure 19: Edge Cloud Site Time Sync Architecture for LLS-C3

Es posible utilizar GPS en lugar de PTP?

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G O-RAN

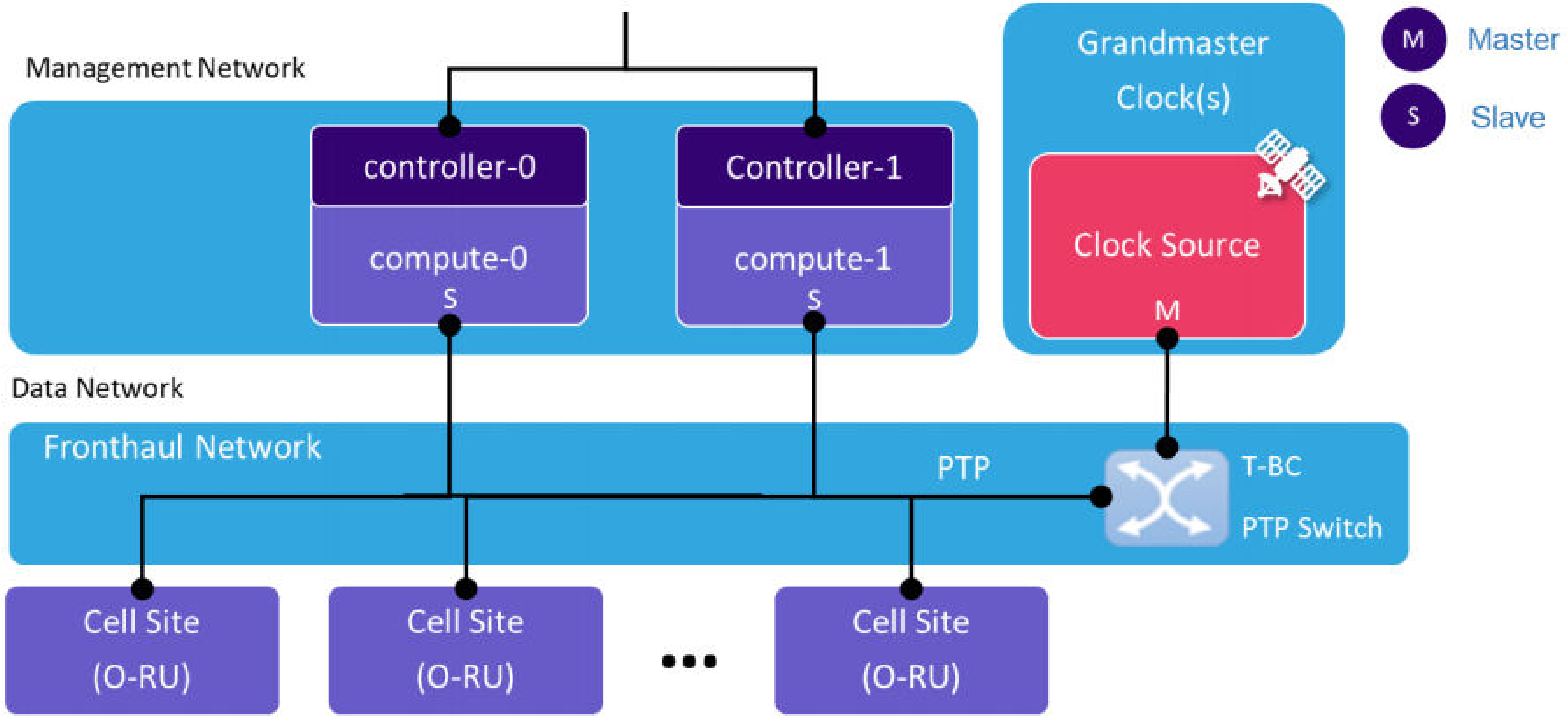


Figure 20: Hyperconverged Edge Cloud Time Sync Architecture for LLS-C3

Es posible utilizar GPS en lugar de PTP?

ESQUEMA GENERAL DE SINCRONIZACIÓN EN 5G

5.5.1.1.2 LLS-C3 Synchronization Topology Edge Site Requirements

To support time synchronization at the Edge site, the cloud platform (O-Cloud) used at the Edge site needs to support implementation of the PTP IEEE 1588-2008 (a.k.a. IEEE 1588 Version 2) standard. The following software and hardware capabilities are required:

5.5.1.1.2.1 Software

Support for PTP will be needed in all the Edge Site O-Cloud nodes that support compute roles and will run vO-DU service operating as a Slave Clock. The following PTP configuration options should be provided:

- Network Transport – G.8275.1 sync over Ethernet (Layer 2)
- Delay Measurement Mechanism – utilize E2E or P2P to measure the delay
- Time Stamping – support for hardware time stamping

For example: in the case when an O-Cloud is based on the Linux OS, this will require support for Linux PTP (see http://linuxptp.sourceforge.net) with the following:

- ptp4l – implementation of PTP (Ordinary Clock, Boundary Clock), HW / SW timestamping, Delay request-response / Peer delay mechanism, and IEEE 802.3 (Ethernet) / UDP IPv4 / UDP IPv6 network transport
- phc2sys – Synchronization of two clocks, PHC and system clock (Linux clock) when using HW timestamping

5.5.1.1.2.2 Hardware

Use of High speed, low latency Network Interface Card (NIC) with support for PTP Hardware Clock (PHC) subsystem for the data interface (fronthaul) on all the compute node(s) that will run the O-vDU function.

Es posible utilizar GPS en lugar de PTP?

REDES DE QUINTA GENERACIÓN
Curso Nivel 2
Módulo 4

CePETel

Prof. José Luis Pellegrino

TEMARIO

MODULO 1
Arquitectura de la red de Red de Acceso.
Protocolos: Capa física, MAC, RLC, PDCP, Capas altas.
Ancho de banda asociado a cada capa.
Modelo de Centralización y de Distribución.
CPRI.

MODULO 2
Arquitectura del Núcleo en redes SA
Concepto de Slicing
Entidades, Interfaces protocolos.
Overlay 5GC con EPC

MODULO 3
La red de transporte en 5G.
Requerimientos de ancho de banda.
Requerimientos de latencia. TSN.
Desagregación de la Red de Acceso.

TEMARIO

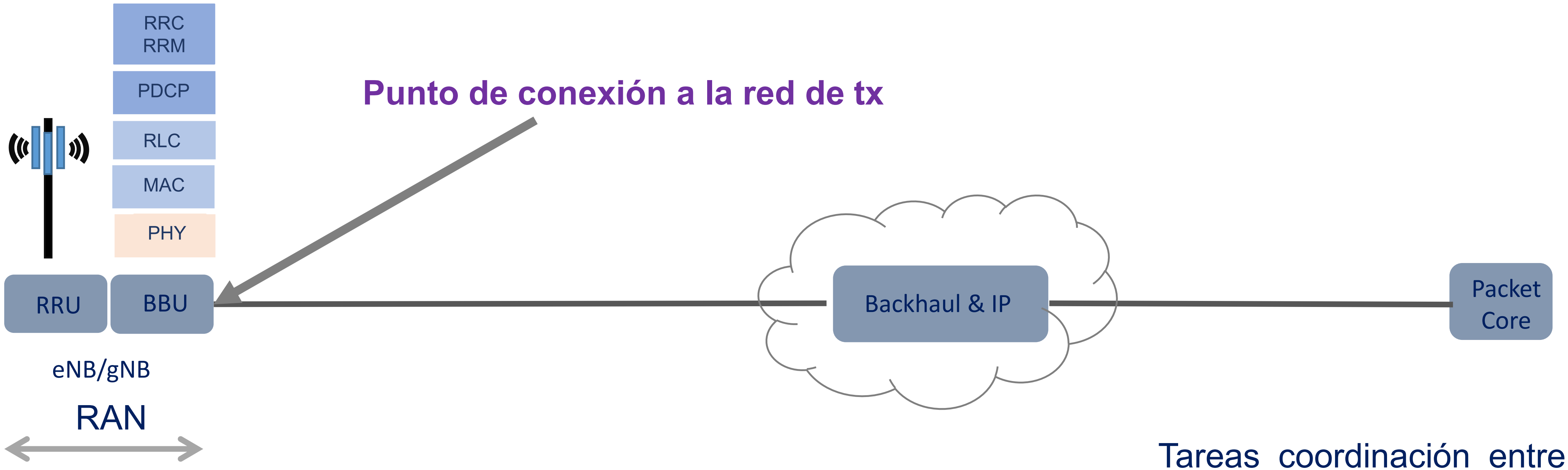
MODULO 4
Open RAN
Arquitectura.
Modelo
Casos y desafíos

MODULO 5
5G Signalling
NWDAF Network Data Analytics Function
SEPP Seurity Edge Protection Proxy

MODULO 6
Automatización
SDN
SON
RIC

RESUMEN DE ASPECTOS QUE CONDUCEN A OPEN RAN

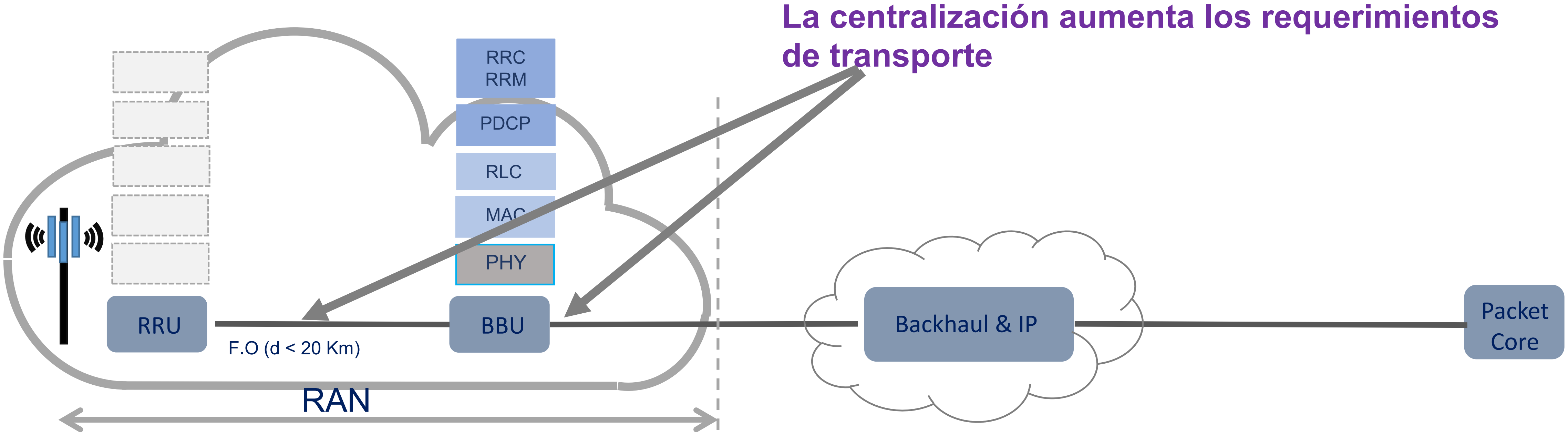
DISTRIBUTED RAN



- Solución RAN nolítica provista por un solo vendor.

Tareas coordinación entre radio bases es limitada (Interfaz X2 de LTE).

CENTRALIZED RAN

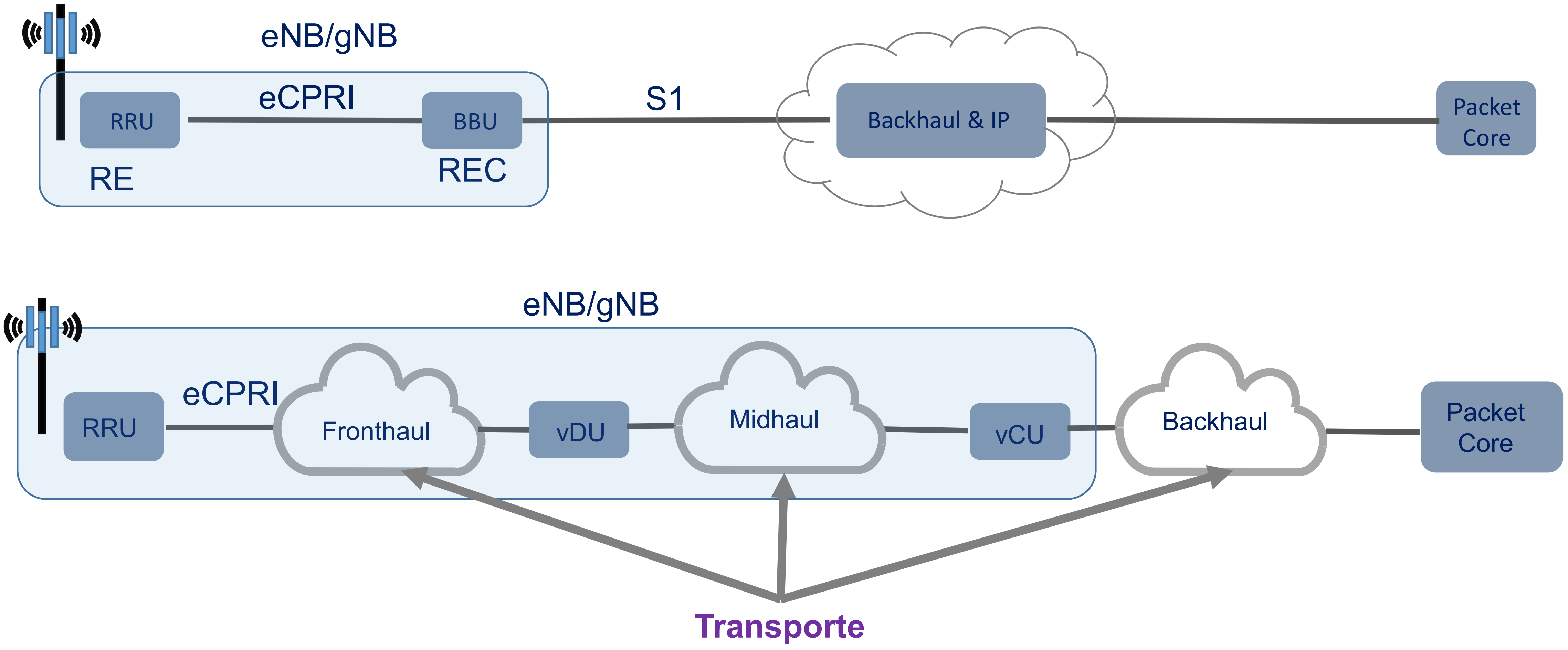


- Solución RAN provista por un solo vendor.
- El máximo grado de desagregación de la RAN es RRU y BBU (modelo granjeado)
- Pool de BBUs en un mismo lugar. BBUs colocalizadas en una central
- RAN localizada en el edge y Packet Core centralizado.
- Solo la capa de radio en el sitio.
- Todas las capas de radio desplegadas en un entorno < 20 kms (Fronthaul).
- Se simplifica el backhaul y el sincronismo
- Solución baremetal.
- CPRI propietario

eNB = RRU +BBU

Sigue siendo válido en 5G?

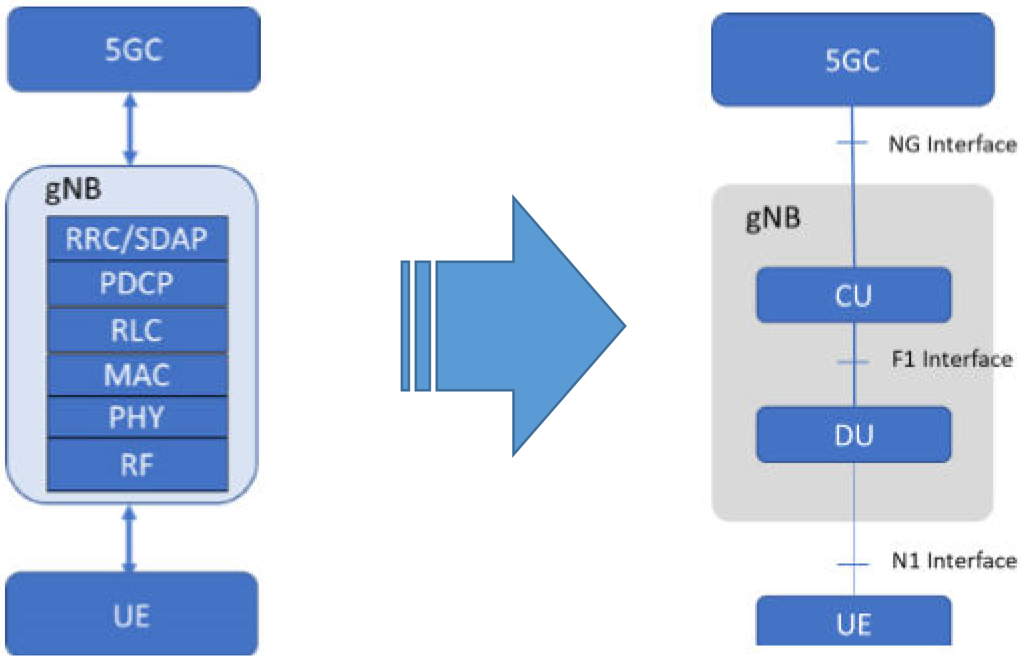
CASOS DE DESAGREGACIÓN



Discutir TSN!! Qué parte de la red cumple con este requisite?

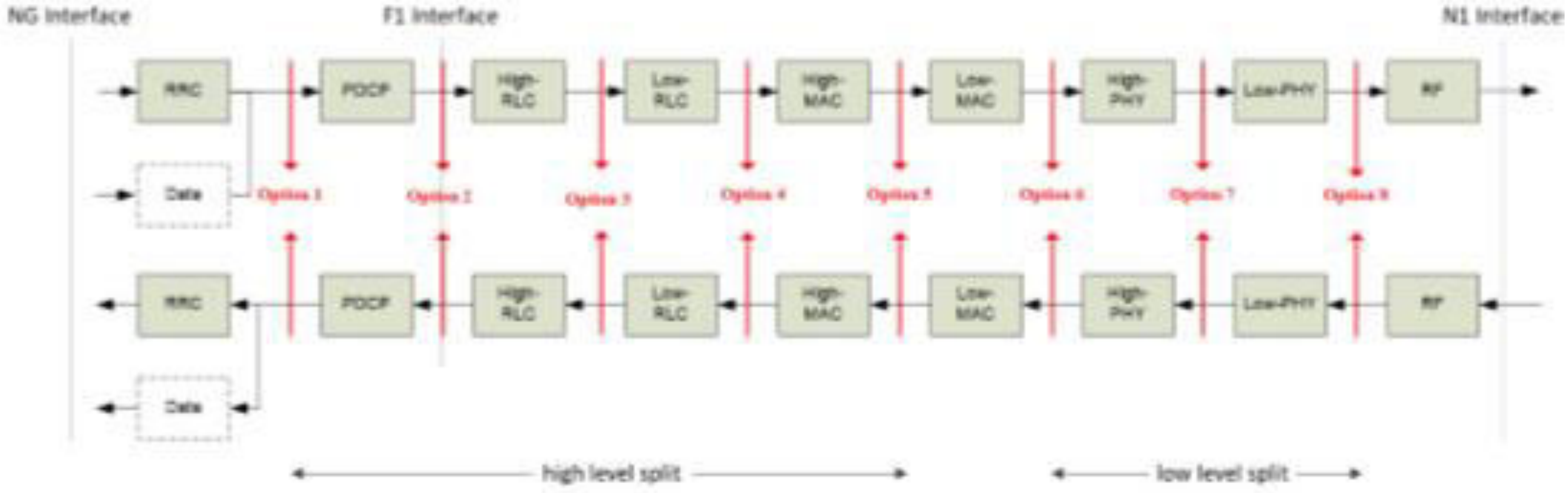
INCIATIVA DE 3GPP. CONCEPTO DE SPLIT DE RAN

3GPP definió una arquitectura RAN de próxima generación (NG-RAN) donde la funcionalidad de la estación base 5G NR (gNB) se divide en dos unidades lógicas: una unidad central (CU) y una unidad distribuida. (DU). En el modelo 3GPP, la CU está conectada al núcleo 5G (5GC) a través de la interfaz NG y la CU está conectada a la DU a través de la interfaz F1, como se muestra a continuación en la Figura 3.



Algunas funciones son Real-Time
Otras no.

INCIATIVA DE 3GPP. DISTINTOS SPLITs DE RAN

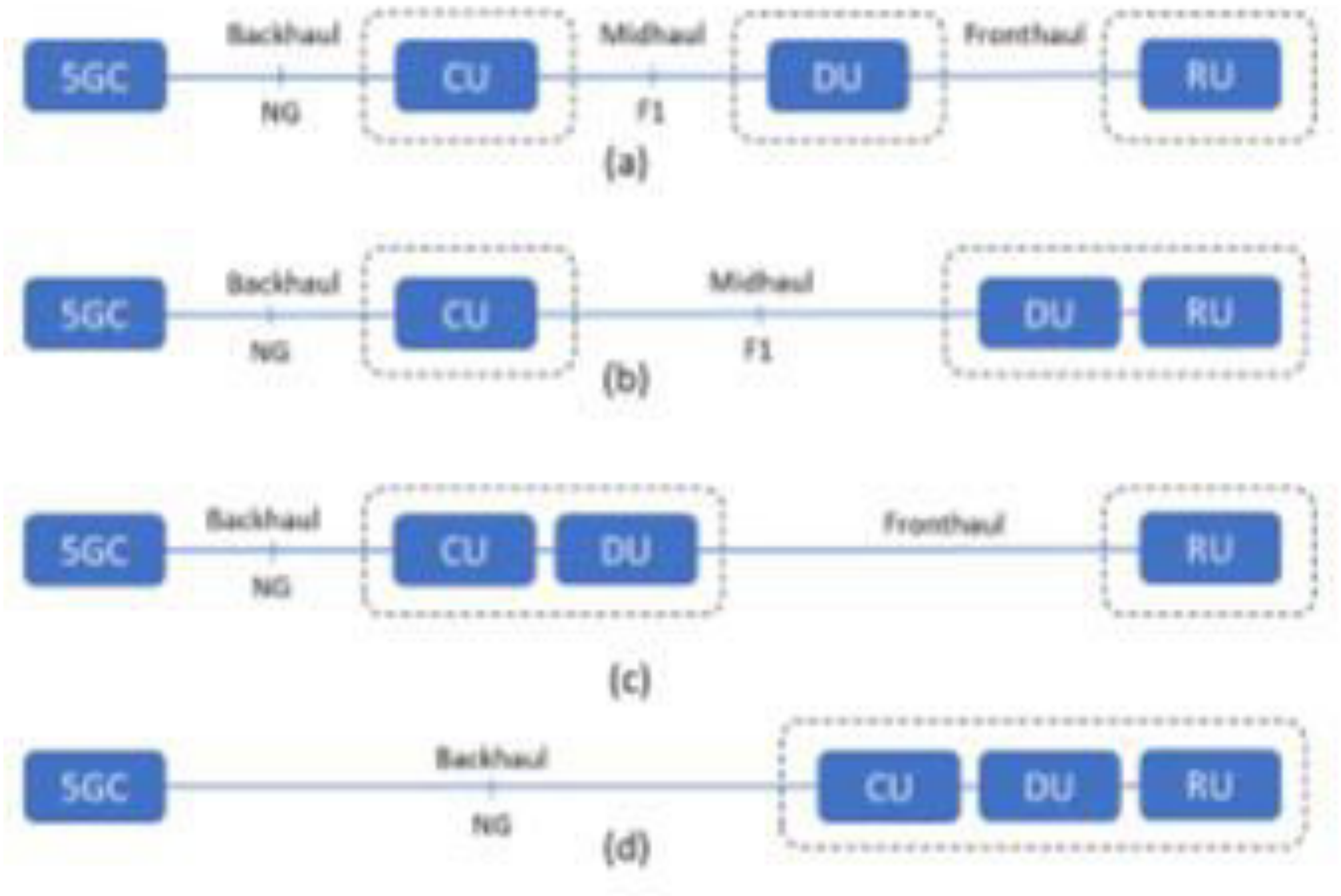


- Las señales de radio en NR constituyen una "cadena de servicios“.
- Se definen interfaces entre funciones, para lograr la desagregación.
- Las funciones que necesitan procesamiento en tiempo real se agrupan dentro de la DU, las que no, en la CU.
- A mayor centralización mayores requerimientos en general.

Split óptimo: topología de red, disponibilidad de fibra, cantidad de usuarios, volumen de servicio, etc

INCIATIVA DE ITU-T. DISTINTOS SPLITS DE RAN

La ITU-T, adoptó una arquitectura de transporte algo diferente para 5G, con tres elementos lógicos: CU, DU, y RU.

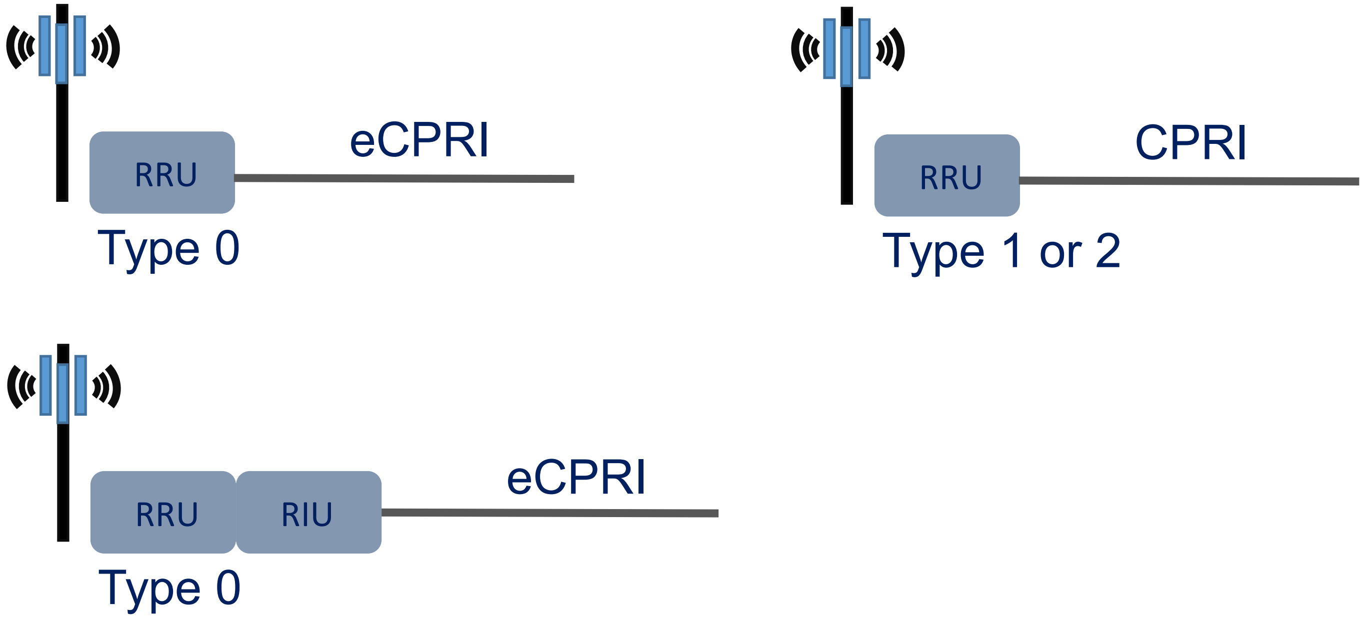


Fronthaul:
CPRI Vs eCPRI
CPRI: split 8 (RRH y BBU).
RRH: RU con una división funcional de Opción 8 (es decir, RF / PHY bajo)
BBU: DU y CU.
CPRI: para transportar muestras digitalizadas en el dominio del tiempo de la señal de banda base entre RRH y BBU

Analizar cada Split. xhaul

LA EVOLUCIÓN A eCPRI

La “CPRI cooperation”, lanzó una nueva versión de la especificación eCPRI (2.0): introduciendo una función de interfuncionamiento a la RU y DU existentes, de modo que CPRI y eCPRI puedan interfuncionar en la red. Un tipo de interfuncionamiento 0 es un dispositivo ubicado entre la red de transporte eCPRI y una o varias unidades de radio, mientras que los dispositivos de tipo 1 y 2 de función de interfuncionamiento se ubican entre los nodos CPRI y la red de transporte.



EL APORTE DE IEEE

Al mismo tiempo, el Instituto de Ingenieros Eléctricos y Electrónicos (IEEE) a trabajar en una Interfaz Fronthaul de Próxima Generación (NGFI).
Hay dos trabajos:

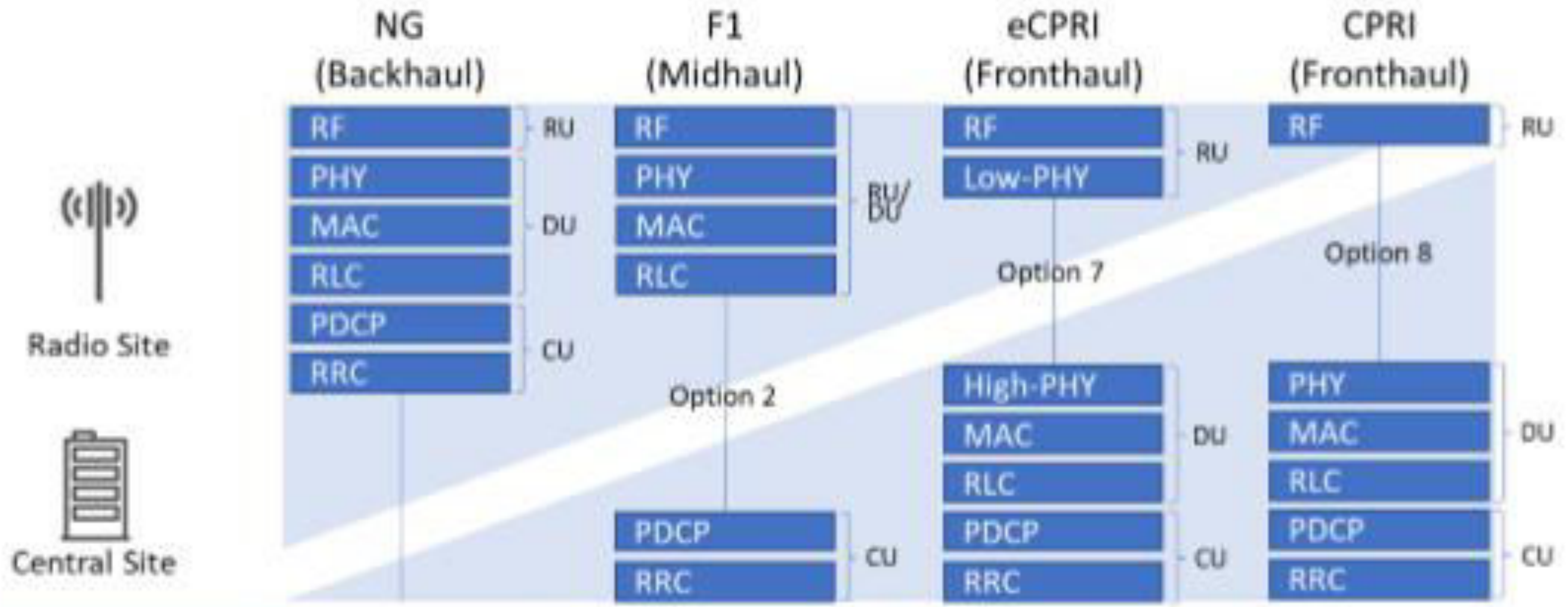
- IEEE 1914.1 cubre los estándares para redes de transporte fronthaul basadas en paquetes.
- IEEE 1914.3 que se encarga de la encapsulación y asignaciones de Radio sobre Ethernet (RoE) que direccionan las divisiones DU / CU en los splits 7.1 / 7.2 y 8.

Los operadores que instalan nueva tecnología NR colocada en sitios LTE existentes están lidiando con el desafío de transportar CPRI y eCPRI hasta que todo el tráfico en el sitio celular sea eCPRI, momento en el cual las redes de conmutación de paquetes se pueden usar en la capa de transporte utilizando nuevos protocolos como Time Sensitive Networking. (IEEE 802.1CM) desarrollado para ofrecer baja latencia y sincronización precisa para el tráfico de fronthaul.

Discutir mapeos entidades duales

RELACIÓN ENTRE SPLITS Y REQUERIMIENTOS DE TRANSPORTE

Requisitos de latencia y velocidad de datos y limitaciones de distancia para las interfaces NG, F1, eCPRI y CPRI.
Ejemplo basado en un sitio de radio con 3 sectores, ancho de banda de canal de 100 MHz, 64 cadenas de transmisión / recepción, 256 QAM, 16 capas MIMO y MIMO multiusuario (MU-MIMO).

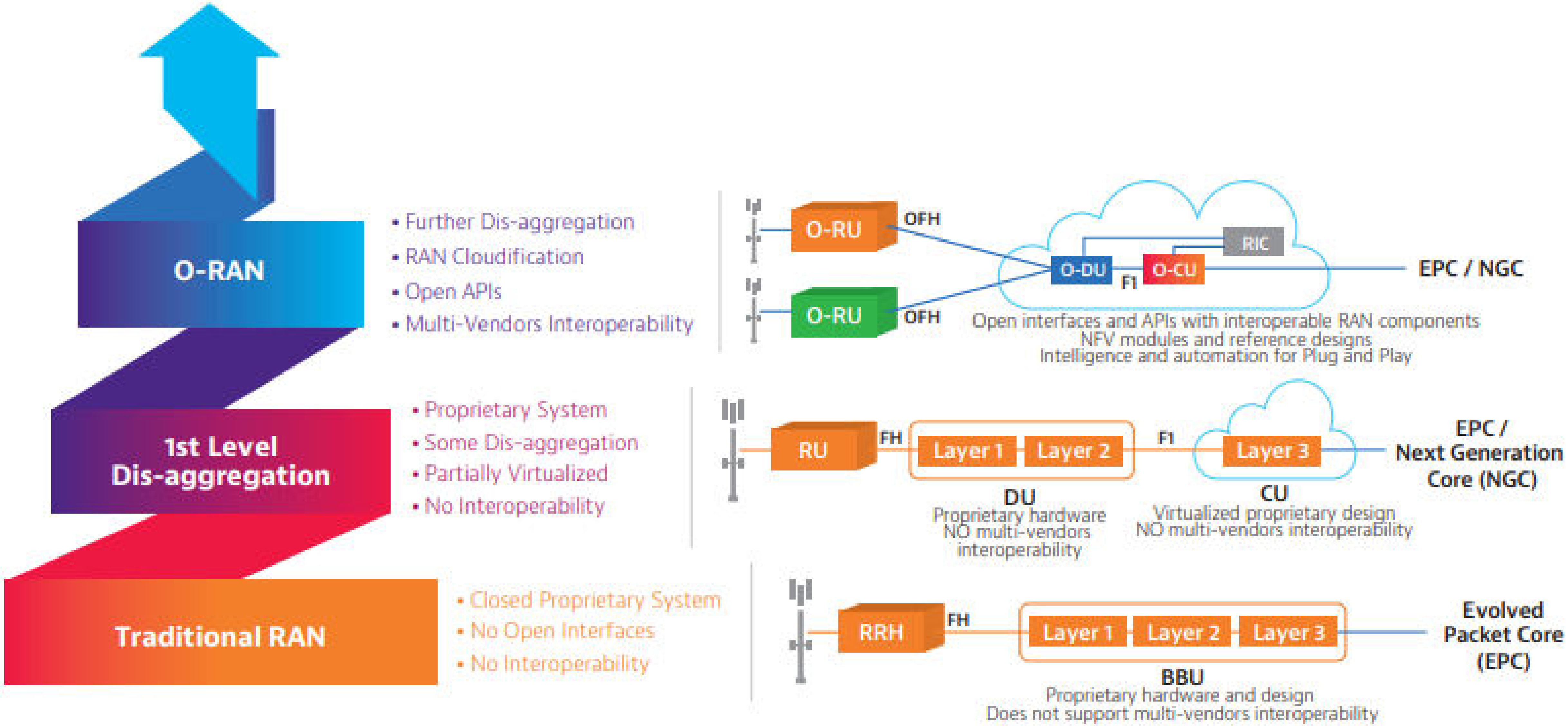


	NG	F1	eCPRI	CPRI
Data Rate	10 Gbps	10 Gbps	100 Gbps	1 Tbps
Latency	< 10 ms	< 5 ms	< 200 µs	< 100 µs
Distance	200 – 500 km	100 – 400 km	< 20 km	< 10 km

Fuente: NOKIA

QUE ES OPEN RAN

INTRODUCCIÓN A O-RAN. EVOLUCIÓN DE LA RAN



OPEN RAN ALIANCE

La Alianza O-RAN anunció en junio de 2018 que lideraría los esfuerzos hacia una RAN abierta con interfaces interoperables y virtualización de RAN. La O-RAN Alliance tiene 9 grupos de trabajo que analizan muchos temas entre los protocolos L2-L3 RAN para la división de capa alta y las opciones L1 (por ejemplo, eCPRI e IEEE1914) para la división de capa baja.

O-RAN también introdujo una nueva arquitectura para el split funcional 7.2. Se especificaron dos categorías: Categoría A y Categoría B. La principal diferencia entre las dos es la ubicación de las funciones de precodificación para el enlace descendente. Los dispositivos de categoría A no tienen funciones de precodificación, mientras que los dispositivos de categoría B incluyen funciones de precodificación.

EL PROBLEMA DE LA CAPILARIDAD EN mmWAVE

Contexto

Incremento en el ancho de banda
Budget de latencia cada vez menor
Redes preparadas para soportar nuevos servicios

Aplicaciones con alta demanda de cómputo
Computing se corre al borde
Consolidación de MEC

Infrraestructura virtualizada (VNFs & Contenedores)
Alineación con políticas de virtualización

La red de acceso se ensancha : Borde & Data Centers
El vínculo con el Core debe ser directo
Centralización & Distribución

Arquitecturas de acceso común 4G & 5G
Desagregación de RAN
Optimización de transporte dentro de la RAN

NUEVA ARQUITECTURA
DE RED DE ACCESO

OPEN RAN

Que es OPEN RAN?

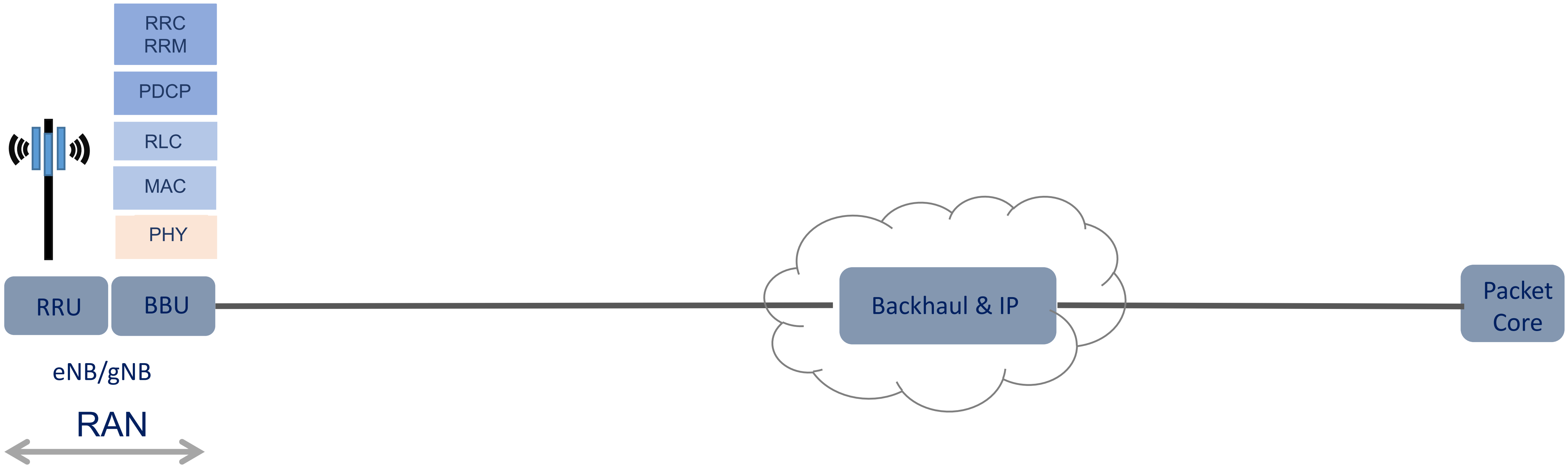
ASPECTOS DUROS

- Una arquitectura de Red de Acceso de nueva Generacion.
  Desagregación y nuevas interfaces
- Interfaces abiertas e interoperables
  BBU se desagrega (split) en nuevas entidades
- Infraestructura virtualizada
  Integración con T-Cloud
- Split de la Banda Base, lo cual reduce latencia
  eCPRI

ASPECTOS BLANDOS

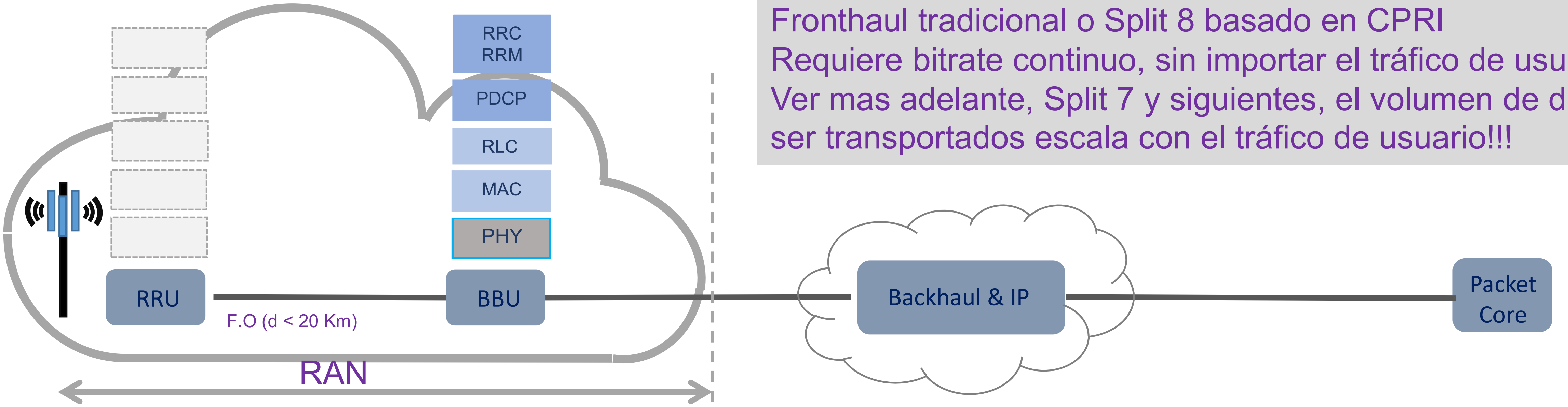
- Diferentes vendors en cada segmento (desagreg de Vendors)
  HW, SW, Radio, Computing, NFVI, etc
- Mayor agilidad en la definición de servicios y reducción de CAPEX
- Ecosistema abierto con HW commercial (COTS)
  HW común a otros servicios
- Arquitectura común
  Misma Arquitectura para 4G & 5G

ARQUITECTURA ACTUAL – DISTRIBUTED RAN



- Solución RAN provista por un solo vendor.
- Arquitectura propietaria. Interconexión RRU-Baseband propietara.
- No existe desagregación.
- SW&HW bundled.
- Limitada innovación.
- Limitada capacidad para despliegue de features inter-site.
- Dificultad para despliegue de aplicaciones de uso intensivo de cómputo.
- Solución baremetal.

ARQUITECTURA ACTUAL – CENTRALIZED RAN. Modelo de Granja



Fronthaul tradicional o Split 8 basado en CPRI
Requiere bitrate continuo, sin importar el tráfico de usuario.
Ver mas adelante, Split 7 y siguientes, el volumen de datos a ser transportados escala con el tráfico de usuario!!!

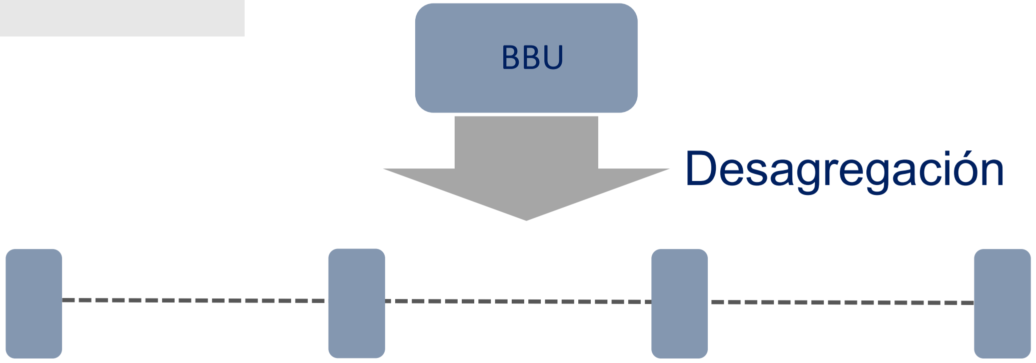
- Solución RAN provista por un solo vendor.
- El máximo grado de desagregación de la RAN es RRU y BBU (modelo granjeado)
- Pool de BBUs en un mismo lugar. BBUs colocalizadas en una central
- RAN localizada en el edge y Packet Core centralizado.
- Solo la capa de radio en el sitio.
- Todas las capas de radio desplegadas en un entorno < 20 kms (Fronthaul).
- Se simplifica el backhaul y el sincronismo
- Solución baremetal.
- CPRI propietario

ARQUITECTURA O-RAN – Punto de partida. Fronthaul y desagregación de BBU

Este modelo de centralización limita la distancia entre la RRU y el punto de conexión al BH

- Datos entre la BBU y la RRU, señales de radio digitalizadas con muestras I/Q de la señal un gran ancho de banda
- Common Public Radio Interface (CPRI) (Split 8)
- Procesamiento de datos en BBU mas transporte < 3mS
- Delay adicional (debido a HARQ entre otros)
- Delay causado por fibra < 100 uS **(20 Km)**

- En la arquitectura ORAN se mantiene el Fronthaul (con algunos cambios, en especial asignación de layers, Split 7 en lugar de Split 8)
- Se introduce la desagregación de la BBU (MH)
- Se introduce concepto de Midhaul)



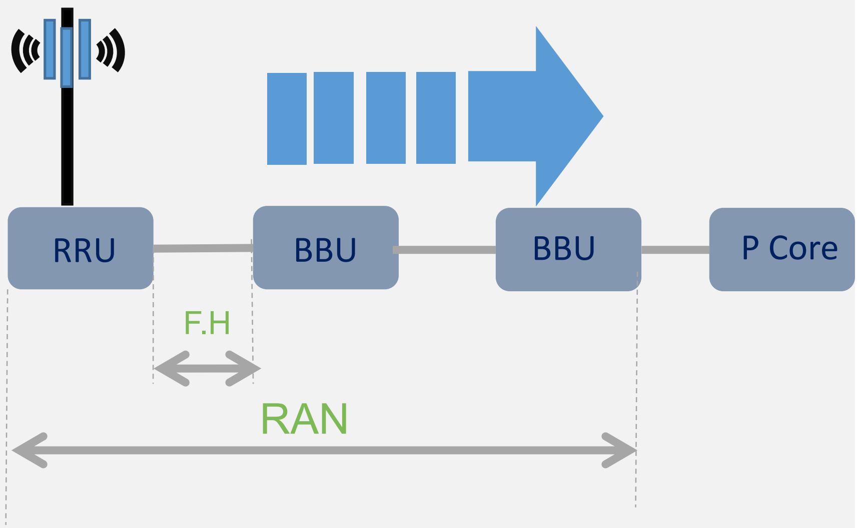
ARQUITECTURA O-RAN. Limitaciones del modelo centralizado tradicional

Pros

- Pooling de recursos, optimiza utilización
- La propia arquitectura ofrece funciones claves para LTA
- Coordinación de multiples radios CoMP para agregación de tráfico
- Usa CPRI que es apropiado en términos de delay, pero……..

Cons

- CPRI es ineficiente en términos de ancho de banda y flexibilidad de los nodos. Tiene un Budget de delay muy limitado (por eso la distancia RRU-BBU debe ser limitada)
- Las tramas CPRI se expanden al aumentar el ancho de banda del canal de radio y el número de elementos de antena.
- Por naturaleza no permite multiplexación estadística, lo cual es una reafirmación de su ineficiencia y no escala para cubrir las demandas de 5G (se requeriría hasta 100 Gbps)



NOTA: Si bien con O.RAN el F.H sigue siendo limitado en distancia, el punto de enlace con el Packet Core se desplaza

Antenna	10 MHz	20 MHz	100 MHz
1	0.49 Gbps	0.98 Gbps	4.9 Gbps
2	0.98 Gbps	1.96 Gbps	9.8 Gbps
4	1.96 Gbps	3.92 Gbps	19.6 Gbps
64	31.36 Gbps	62.72 Gbps	313.6 Gbps

ARQUITECTURA O-RAN. Lineamientos que rigen la desagregación

- Reducir la tasa de bits (uso de capacidad) en FH
- Adminsitrar latencia estricta (por la propia RAN y para uRLLC)
- Optimizar requisitos de sincronización y jitter para funciones de coordinación como CoMP y CA
- Reducir costos en especial rentabilizar fibra

Grupos de Standarización (3GPP, IEEE, ITU-T y otros)

- Estudian diferentes opciones de SPLIT (1 al 8)
- Objetivo: Identificar los requisitos óptimos para diferentes aplicaciones y servicios (rendimiento, latencia, jitter, etc.)
- Identificar desafíos y soluciones potenciales para dividir las diferentes capas de BBU para satisfacer las demandas de la aplicación y la red
- Focalizar en la performance del Split asociado a FrontHaul

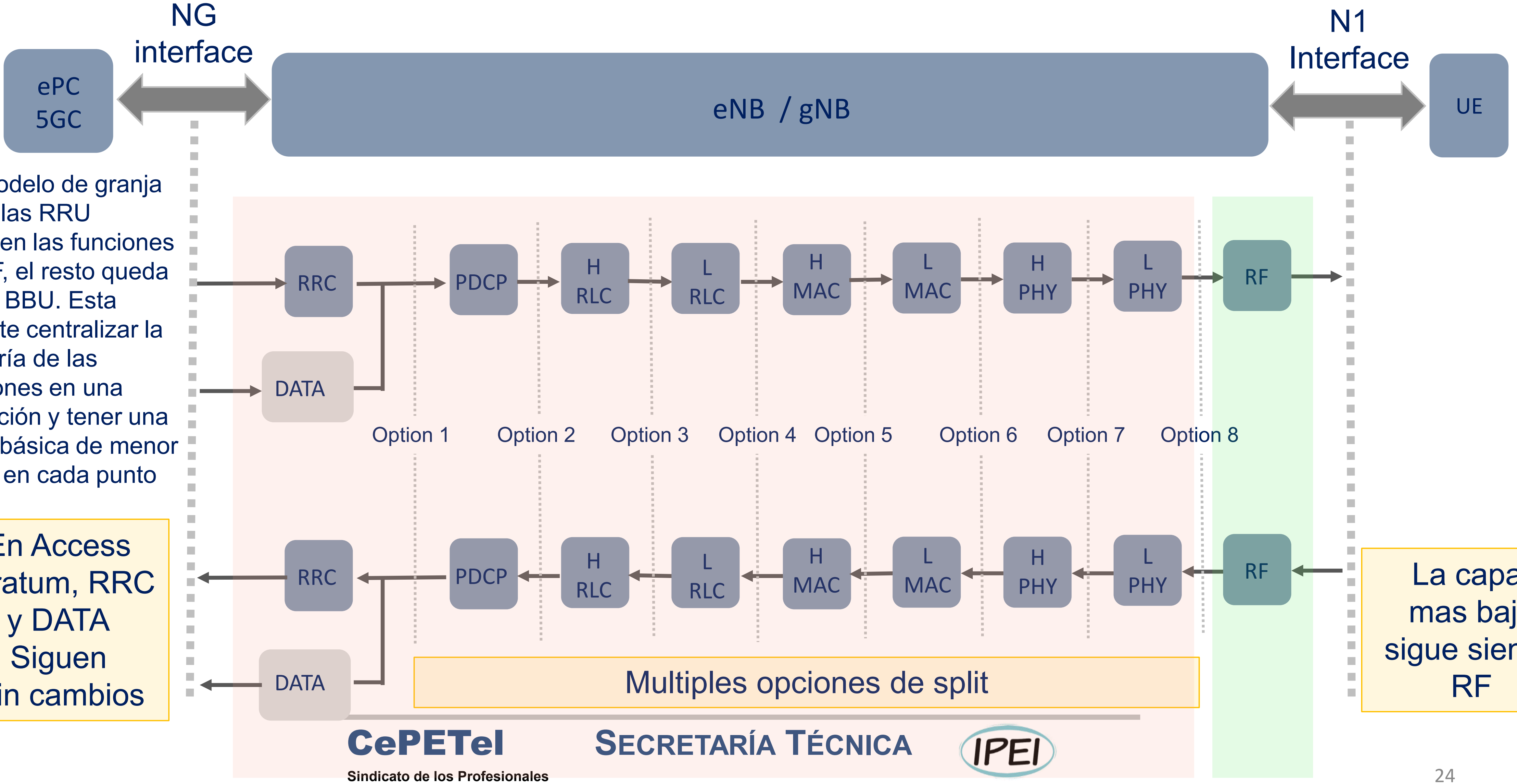
RU DU CU

La capa física lleva a cabo un gran número de funciones.
Un Split de esa capa permite optmizar la demanda de throughput

Split 7 → Split 7-1, Split 7-2, Split 7-3

ARQUITECTURA O-RAN. Modelo general de desagregación

Modelo de ITU-T

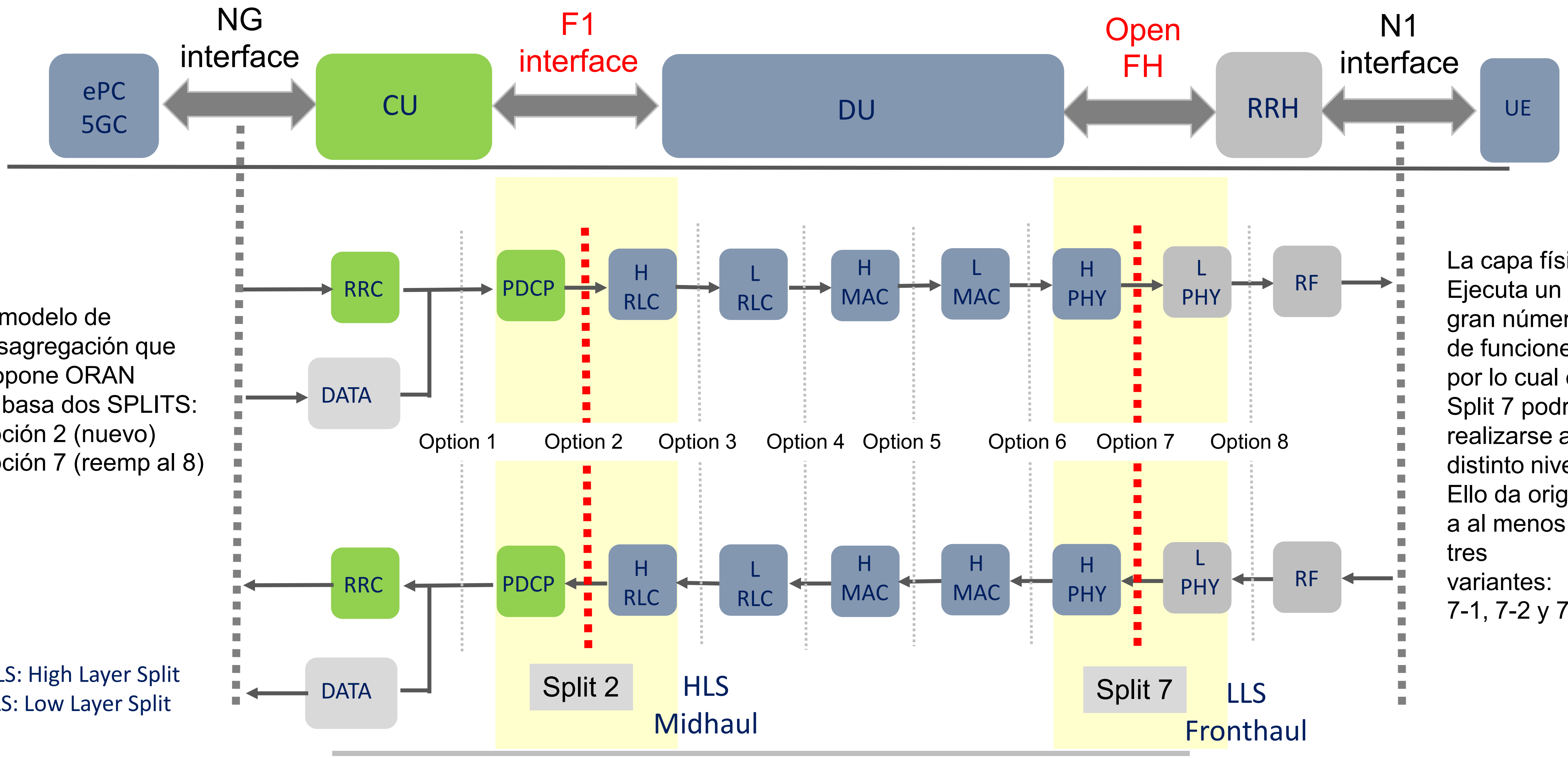


En modelo de granja Trad, las RRU retienen las funciones de RF, el resto queda en la BBU. Esta permite centralizar la mayoría de las funciones en una ubicación y tener una radio básica de menor costo en cada punto final

En Access Stratum, RRC y DATA Siguen sin cambios

La capa mas baja sigue siendo RF

ARQUITECTURA O-RAN. Desagregación CU-DU



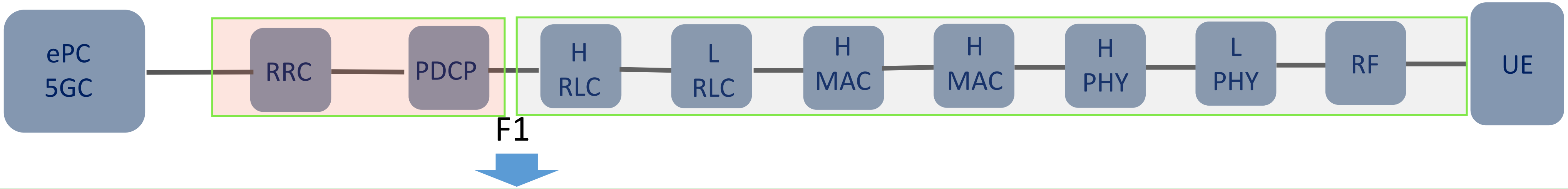
El modelo de desagregación que propone ORAN se basa dos SPLITS:
Opción 2 (nuevo)
Opción 7 (reemp al 8)

HLS: High Layer Split
LLS: Low Layer Split

La capa física Ejecuta un gran número de funciones, por lo cual el Split 7 podría realizarse a distinto nivel. Ello da origen a al menos tres variantes: 7-1, 7-2 y 7-3

ARQUITECTURA O-RAN. Desagregación CU-DU. Midhaul

HLS: Midhaul Split 2, High Layer Split

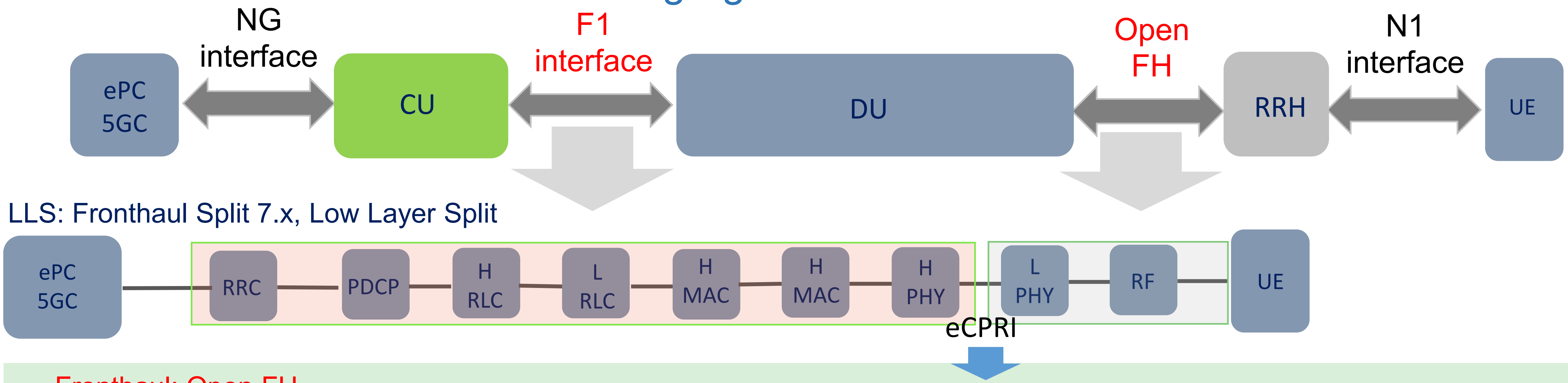


- Midhaul: F1
- Para aplicaciones fijas se recomienda higher layer split (HLS)
- Esta opción deja afuera las funciones real-time (que quedan dentro de la DU /RRU.
- Se reduce notablemente el ancho de banda en la interface HLS
- 3GPP recomienda la opción 2 para HLS
- Delay budget en el rango de varios mS (5 mS), mucho mayor a lo que se requiere en las interfacs CPRI (fronthaul)
- La CU puede estar ubicada a varios cientos de km de la DU/RU.
- Refiere a “Distribución”

CENTRALIZAR SIEMPRE QUE SE PUEDA

DISTRIBUIR DONDE SE DEBA HACER

ARQUITECTURA O-RAN. Desagregación CU-DU. Fronthaul



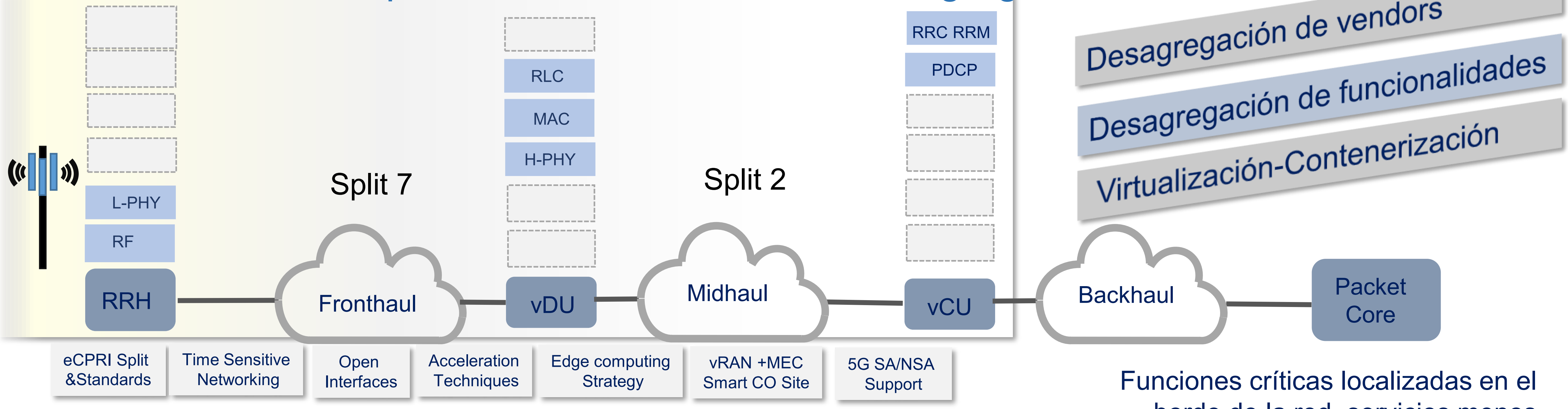
- Fronthaul: Open FH
- Lower layer split (LLS)
- Se considera la opción 7
- Este split functional crea una interface FH que reduce el bit rate para UL y DL.
- Introduce requerimientos de latencia muy estrictos.
- Para este caso de uso la CPRI organization creó eCPRI.
- eCPRI. Tanto Ethernet (capa 2) como Ethernet/IP/UDP (capas 2/3/4) son posibles.
- La trama incluye un encabezado eCPRI que sigue la capa 2 o las capas 2/3/4 el cual es seguido por la carga eCPRI (payload).

- Refiere a “Centralización”. Ahora FH es D-RAN, no C-RAN

CENTRALIZAR SIEMPRE QUE SE PUEDA

DISTRIBUIR DONDE SE DEBA HACER

Introducción a la Arquitectura de OPEN RAN- Desagregación



RAN desagregada a lo largo de un entorno muy distribuído

- La arquitectura de OPEN RAN apela a un mayor grado de desagregación.
- BBU se divide en dos entidades vDU y vCU.
- El borde aún puede ser desagregado. Far Edge y Edge.
- Se mantienen en el Far Edge las funciones de latencia críticas.
- Se lleva al Edge las funciones factibles de ser concentradas en la proximidad del Core.
- Solución virtualizada.
- HW para aceleración
- 4G & 5G. No soporta generaciones anteriores (*)

(*): TIP está reconsiderando esto

Funciones críticas localizadas en el borde de la red, servicios menos sensibles colocadas en sitios centralizados

La definición de midhaul es principalmente impulsada por la próxima generación de redes 5G, la cual requerirá altos anchos de banda y estrictas especificaciones de sincronización, jitter y latencia para el fronthaul.

Introducción a la Arquitectura de OPEN RAN- C-RAN VS D-RAN

D RAN, SPLIT 2

Considerando la localización de las funciones de DU y CU, se puede decir que DRAN es una arquitectura apta para aplicaciones de mMTC (massive Machine Type Communications) y eMBB (enhanced Mobile Broadband) pero no es recomendable para aplicaciones de ultra baja latencia.
Ello significa que para URLLC, la CU (y posiblemente también el plano de usuario de P Core) se deberán lo mas próximo a la DU.

No confundir la latencia impuesta por la RAN (F.H) con la latencia del servicio final

C RAN, SPLIT 7-X

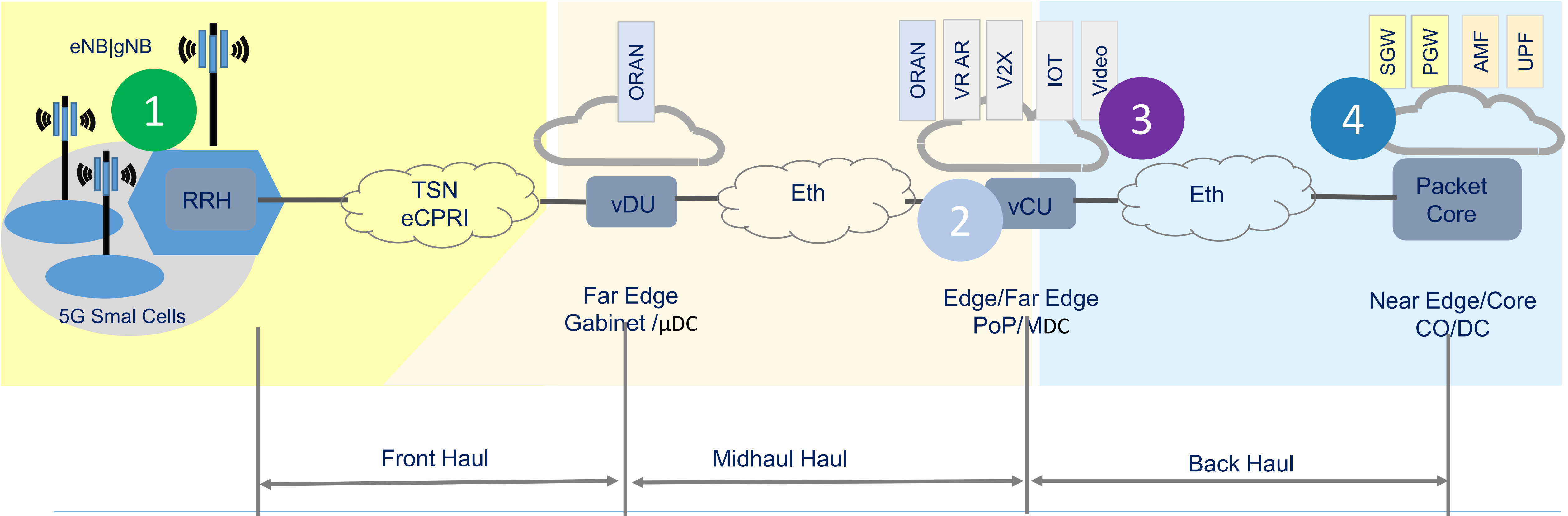
El Split funcional 7.x entre RRU (parte superior de la torre y la DU (o CU/DU) en parte inferior de la misma o en una central que asegure latencia menor a 100 uS, cumple al mismo tiempo con la latencia impuesta por la red, y por los servicios.
En otras palabras, el FH correctamente diseñado no condiciona los servicios finales.

Combinación de SPLIT 2 y SPLI7.X

Se recomienda extender el F.H SPLIT 7 (eCPRI) a la mayor cantidad posible de sitios.
Se recomienda usar M.H SPLIT 2 para servicios no críticos en latencia

Introducción a la Arquitectura de OPEN RAN- Consideraciones sobre el borde.

Edge has become a fundamental and essential prerequisite for 5G wireless.



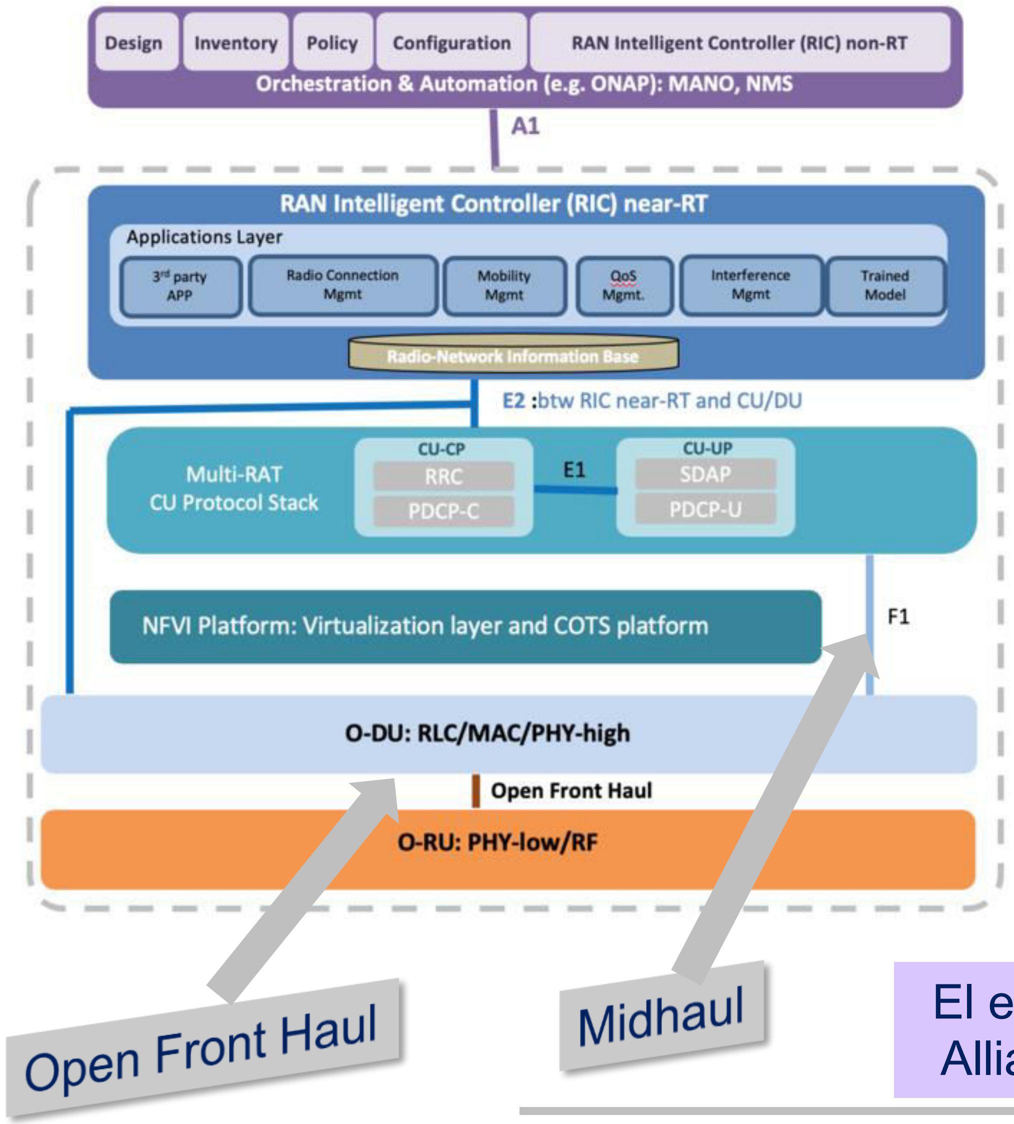
1
- Improved Small Cell deployment
- Capacity Management

2
- Multi.RAT VNF Resource pooling
- Improved Multi-Cell Coordination

3
- Colocate Network Edge Compute / MEC
- Local Breakout
- 5G use cases

4
- Architecture future proofing
- vEPC to 5G CN migration

Marco Normativo. Definición de Arquitectura O-RAN Alliance (www.o-ran.org)



The O-RAN Reference Architecture is designed to enable next generation RAN infrastructures. Empowered by principles of intelligence and openness, the O-RAN architecture is the foundation for building the virtualized RAN on open hardware, with embedded AI-powered radio control, that has been envisioned by operators around the globe. The architecture is based on well-defined, standardized interfaces to enable an open, interoperable supply chain ecosystem in full support of and complimentary to standards promoted by 3GPP and other industry standards organizations.

La arquitectura de O-RAN sigue los lineamientos de NFVI y WhiteBox . Los trabajos de standarización se llevan a cabo en varios grupos de Trabajo:

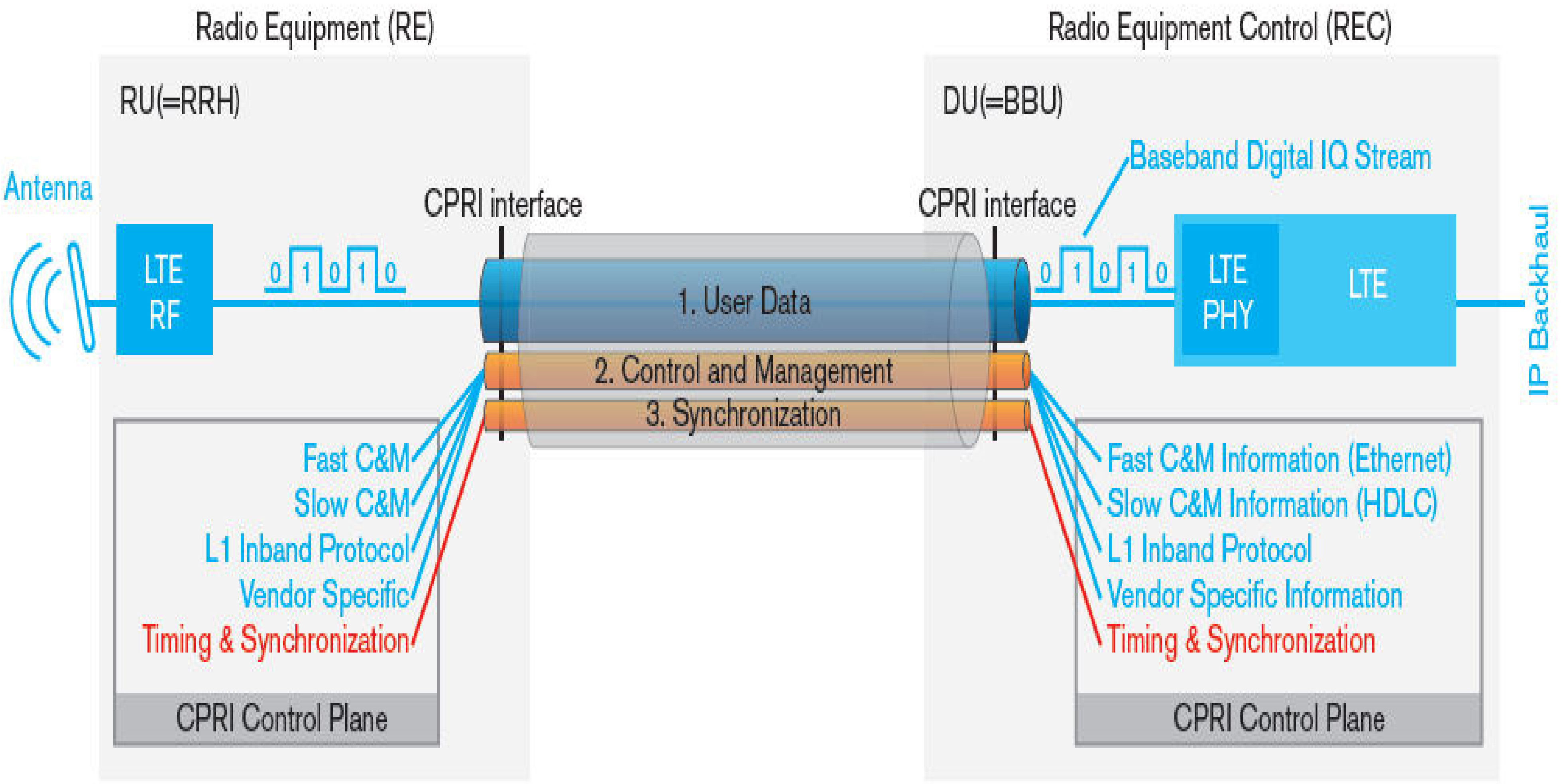
WG2: Non Real Time RAN Intelligent Controller (A1)
WG3: Near Real Time RAN Intelligent Controller (E2)
WG8: Stack Reference Design (E1)
WG5: Open F1/W1/W2/X2/Xn Interfaces (E1 F1)
WG4: Open Front Haul Interface (DU- RU)
WG7: Virtualization &White Box
WG6: Cloudification & Orchestration

El enfoque de Open FH de ORAN Alliance está alineado con ITU-T 8

https://vimeo.com/392657851
https://vimeo.com/392657851

Open RAN- Detalle de Fronthaul en D RAN. CPRI

CPRI



T/P G.8265

Discutir acerca de los profiles de la norma IEEE 1588

Open RAN- Detalle de Fronthaul en D RAN. CPRI

CPRI

- Desarrollado en 2003 como interfaz común.
- Corre entre RRH y BBU.
- RRH, equivalente a RRU con split Option 8 .
- BBU es equivalente a una DU y CU combinadas.
- Transporta muestras digitales banda base del tipo “time-domain”.

CPR1	614.4 Mbps
CPR2	2.457 Gbps
CPR3	9.83 Gbps
CPR4	12.165 Gbps

Ventajas:

- Simplifica los equipos en el sitio.
- Ahorra energia en el sitio, baja el OPEX .

Permitió el desarrollo del modelo C RAN lo cual fue un un paso evolutivo importante

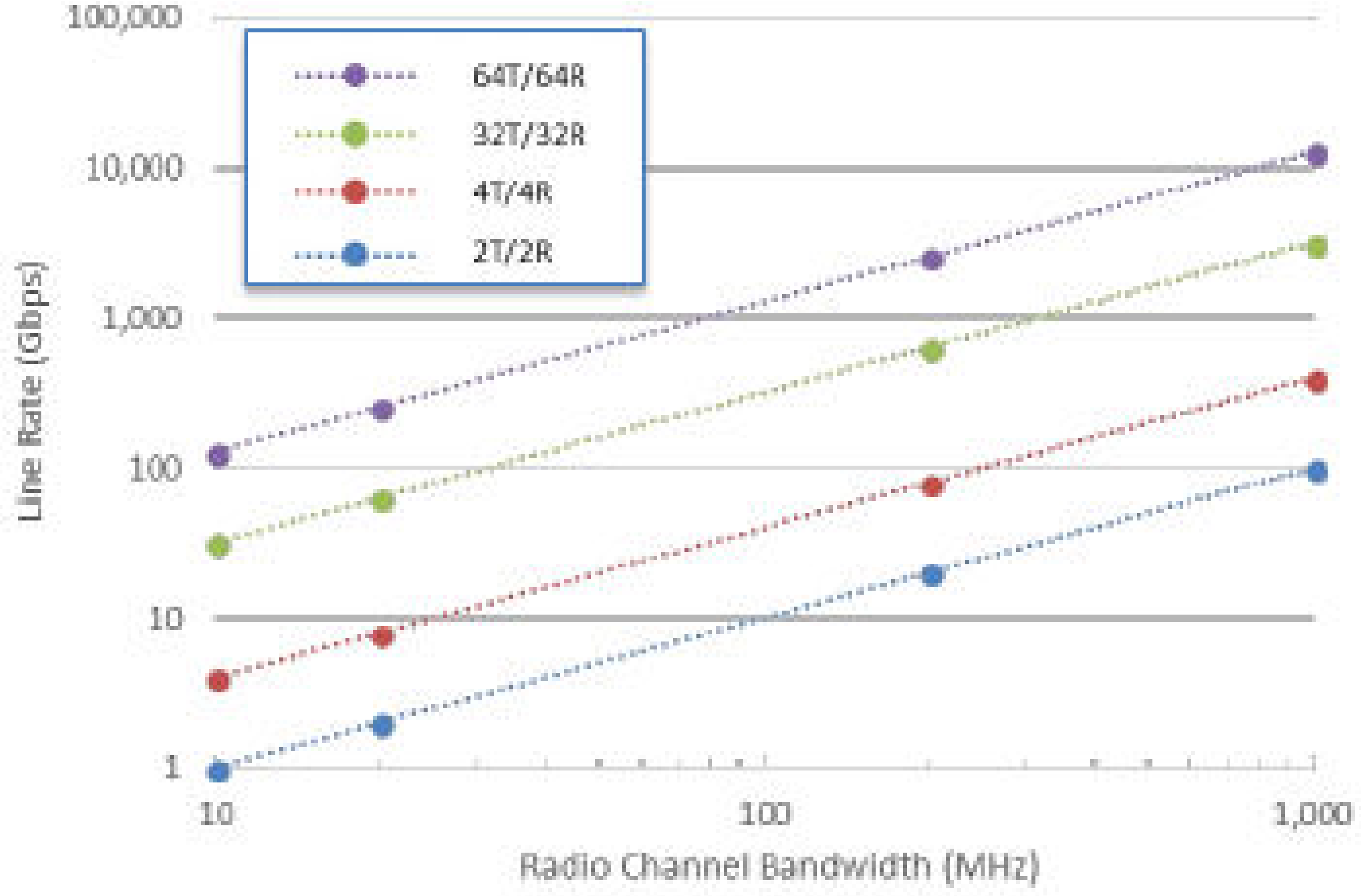
Desventajas y limitaciones:

- Requiere conectividad directa “point-to-point”(fibra oscura).
- Ineficiente. Altos requerimientos de ancho de banda. (2.4 Gb/s for 2x2 MIMO, 20 MHz).
- No soportaría las demandas de BW en 5G, en especial con massive MIMO. mMIMO con 5G requerirá hasta 100 Gb/s fronthaul.
- Bitrate constante aún sin tráfico
- Información “Vendor especifica” (problemas de interoperabilidad).

No obstante, no es adecuado para Open RAN especialmente para 5 G

Open RAN- Detalle de Fronthaul en D RAN. CPRI

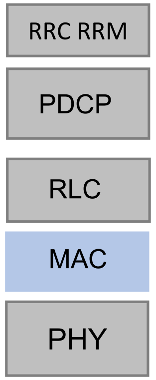
Crecimiento en la demanda de ancho de Banda en el Fronthaul en 5G



Open RAN- Detalle de Fronthaul en D RAN. CPRI Vs eCPRI

Como atacar la latencia en el Fronthaul

La MAC no puede centralizarse porque



- El Scheduling ocurre en la MAC
- La capa MAC tiene exigencias de latencia y jitter muy bajos para llevar a cabo acciones en cada intervalo de tiempo de transmisión (TTI).
- MAC instruye al control de enlace de radio (RLC) sobre el tamaño de los paquetes que recibirá, asegurando así una calidad de servicio (QoS) específica para cada portador de radio.
- Mover la capa MAC a la CU puede limitar potencialmente el desempeño de las funciones de coordinación.
- El proceso Hybrid ARQ (HARQ) y otras funciones críticas de sincronización son parte de un MAC inferior, por eso las divisiones de 6 a 8 tienen fronthaul muy estricto requisitos de latencia.

Notas sobre ACM y HARQ

Modulación Codificación Adaptativa (ACM), Hybrid Automatic Repeat Request (HARQ)
Ambos trabajan juntos proveyendo de un mecanismo de transmisión adaptativo.
ACM selecciona la combinación modulación /codificación a utilizar de acuerdo con las condiciones del canal de radio. Por ejemplo: 64QAM5/6 para excelentes condiciones, QPSK ½ para malas condiciones.
H-ARQ se encarga de retransmitir la información perdida o corrompida utilizando mayor redundancia en las sucesivas retransmisiones hasta que el paquete sea decodificado correctamente.
La combinación de ambos permite optimizar el throughput frente a las condiciones variables del canal de radio.

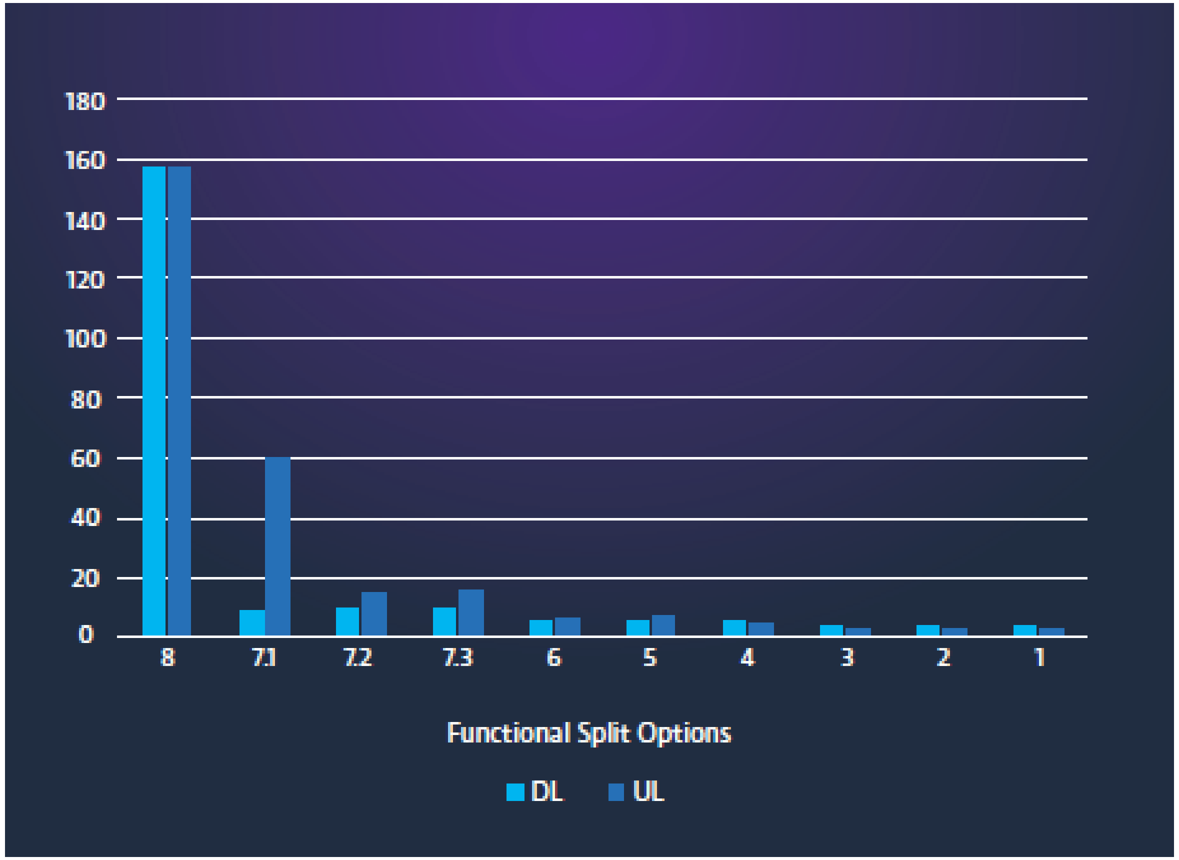
Evaluar costos por el despliegue de Edge GMs

Open RAN- Detalle de Fronthaul en D RAN. CPRI Vs eCPRI

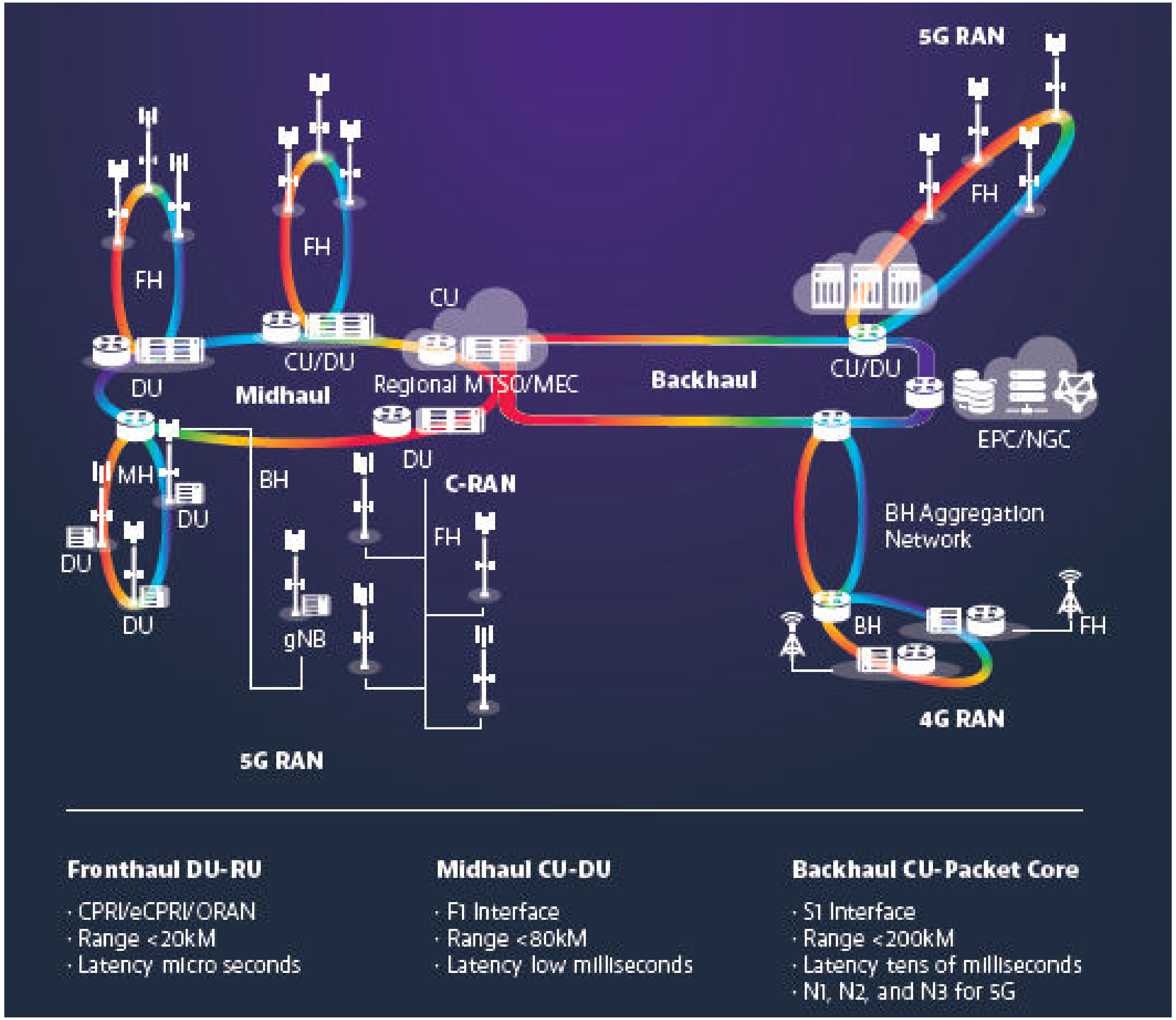
Como atacar el bit rate en el Fronthaul

Cual es el criterio para seleccionar el Split correcto en el FrontHaul?

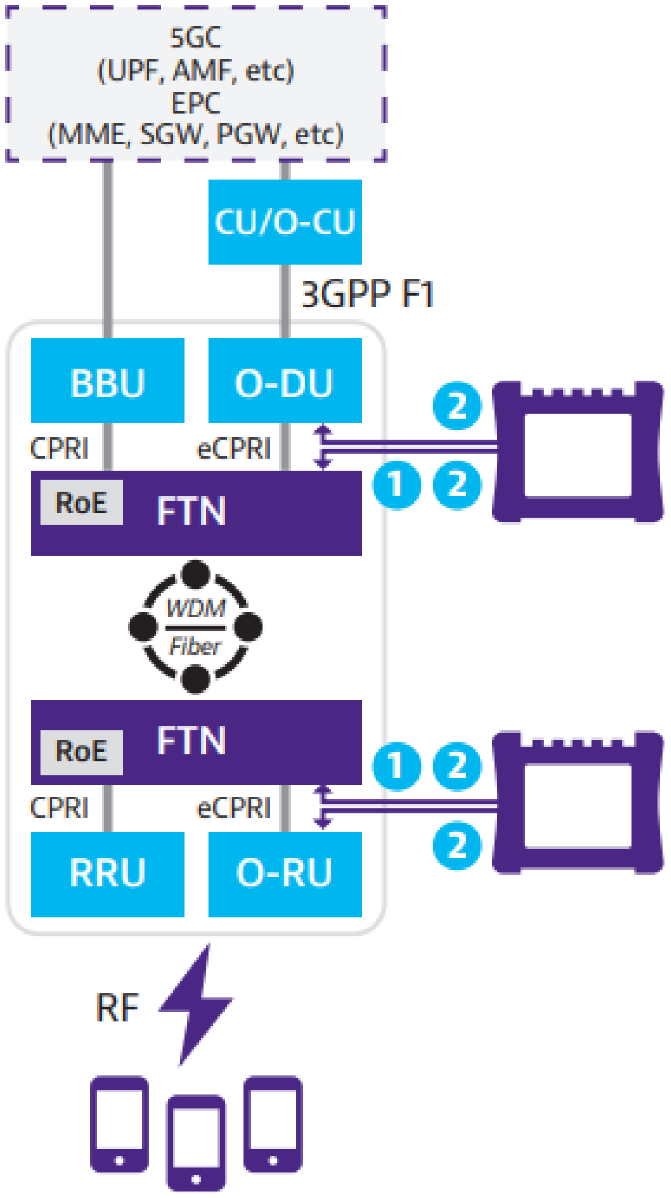
Se debe definir qué Split se usará con eCPRI



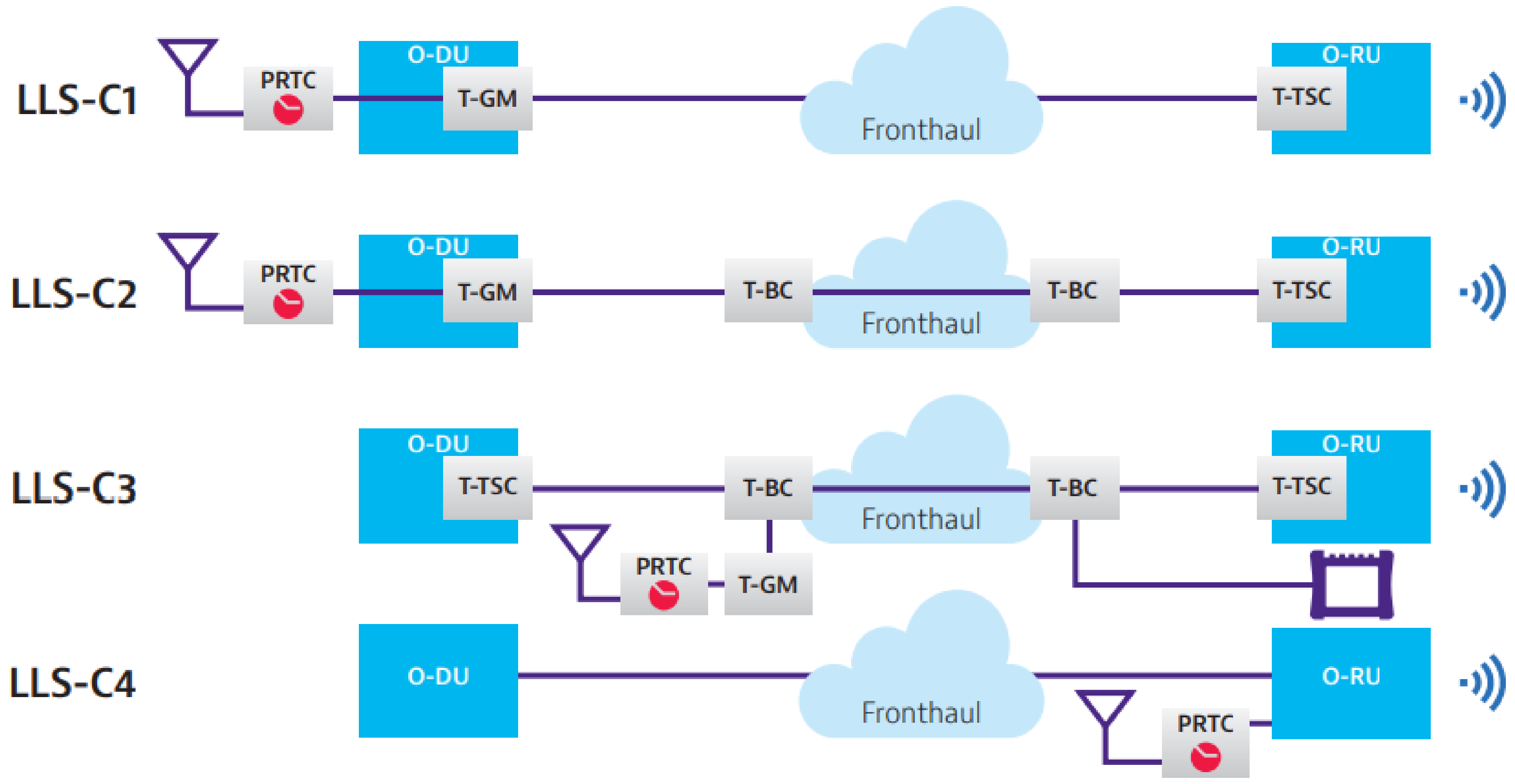
Open RAN- Modelo general



Open RAN- Modelo general

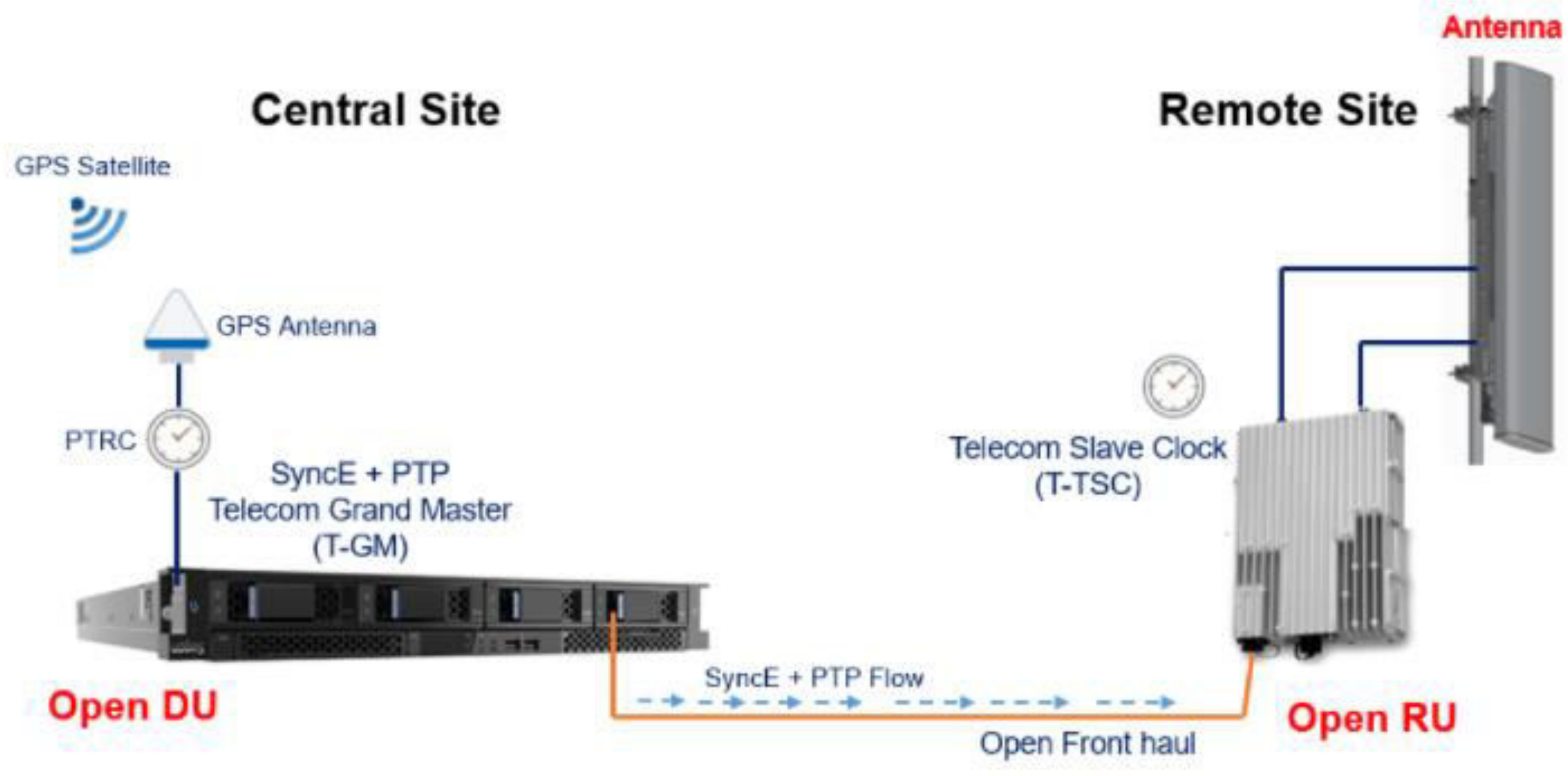


Open RAN- Sincronismo en el Fronthaul. Variantes



Open RAN- Sincronismo en el Fronthaul

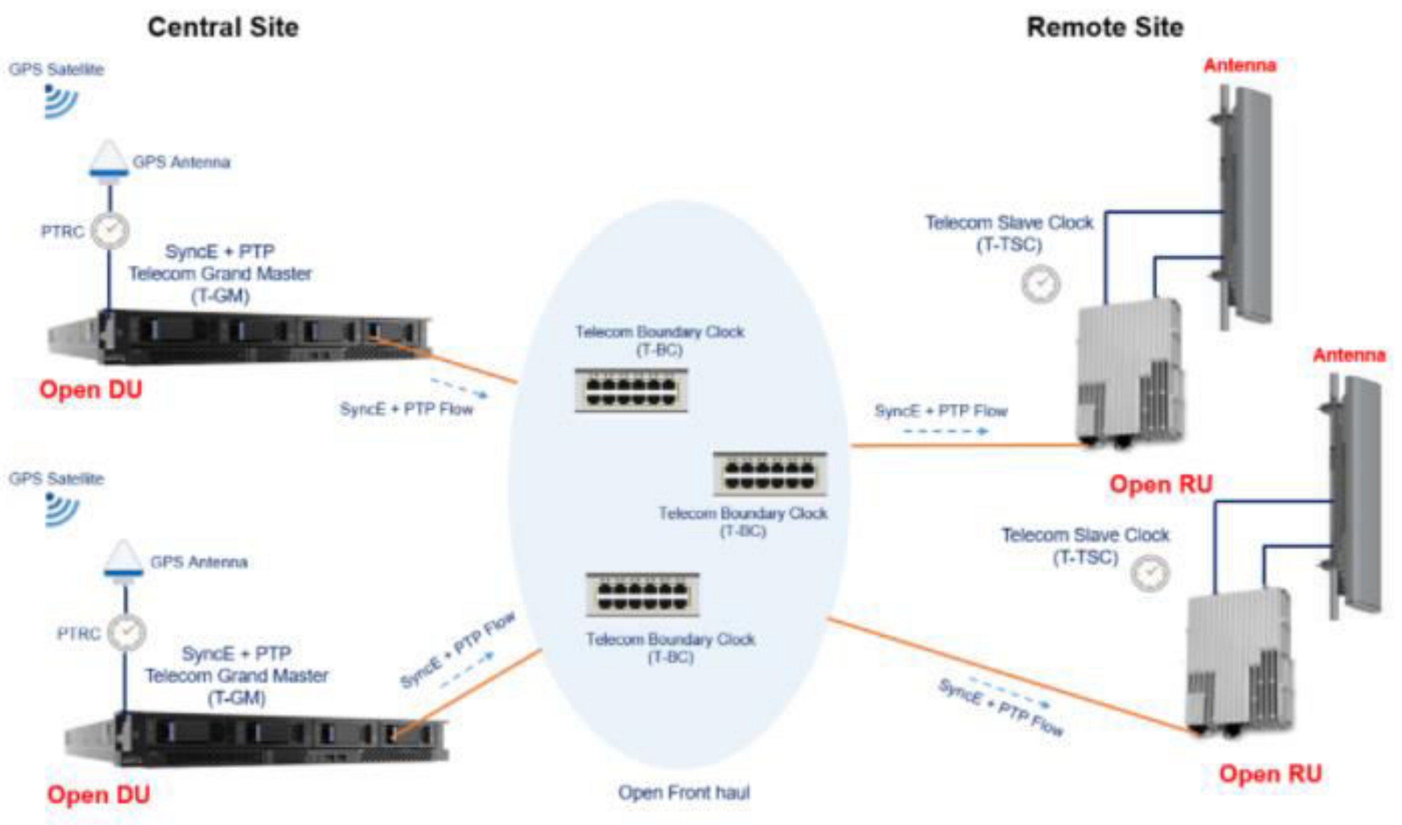
Configuration LLS-C1 is based on point-to-point connection between O-DU and O-RU using network timing option. It is basically the simplest topology for network timing option, where O-DU directly synchronizes O-RU.



https://www.techplayon.com/o-ran-fronthaul-transport-synchronization-configurations/

Open RAN- Sincronismo en el Fronthaul

Configuration LLS-C2 is somewhat similar to LLS-C1 where O-DU acting as PTP and SyncE master to distribute network timing toward O-RU. The synchronization SYNCE+PTP master is located at the O-DU. Further, all Ethernet switches in the fronthaul function as Telecom Boundary Clocks (T-BC). One or more Ethernet switches are allowed between the O-DUs at central site and the O-RUs at remote site. The allowed no. of switches in the PTP and SyncE path is limited by frequency and time error contributions by all clocks in the chain. Interconnection among switches and fabric topology (e.g. mesh, ring, tree, spur etc.) can be done based on deployment scenario. Frequency and Timing budgets and network configuration to ensure 4G and NR Timing Alignment Error requirements and frequency accuracy requirements should be met.



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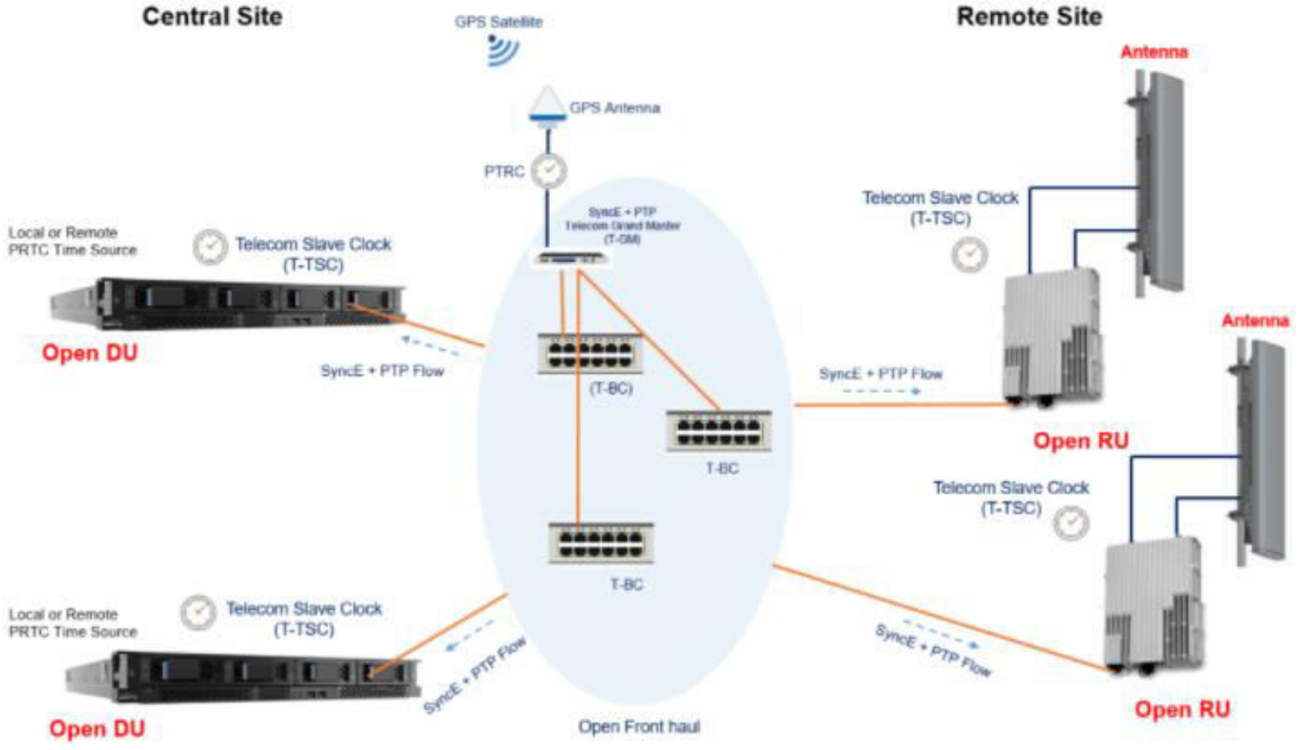
Open RAN- Sincronismo en el Fronthaul

Configuration LLS-C3 support network timing distribution from PRTC/T-GM to O-RU between central sites and remote sites. It means that one or more PRTC/T-GM (acting as SYNCE+PTP master) can be implemented in the fronthaul network to distribute network timing toward O-DU and O-RU as shown in following figure.

•A network topology of Ethernet switches can be used in the fronthaul transport network.

•Interconnection among switches and fabric topology (for example mesh, ring, tree, spur etc.) are deployment decisions.

•O-DU does not act as SYNCE and PTP Master towards the fronthaul interface. It can select its own synchronization from local or remote PRTC like in LLS-C1/LLS-C2, but can also select the same SYNCE and PTP distribution from the fronthaul as the O-RU



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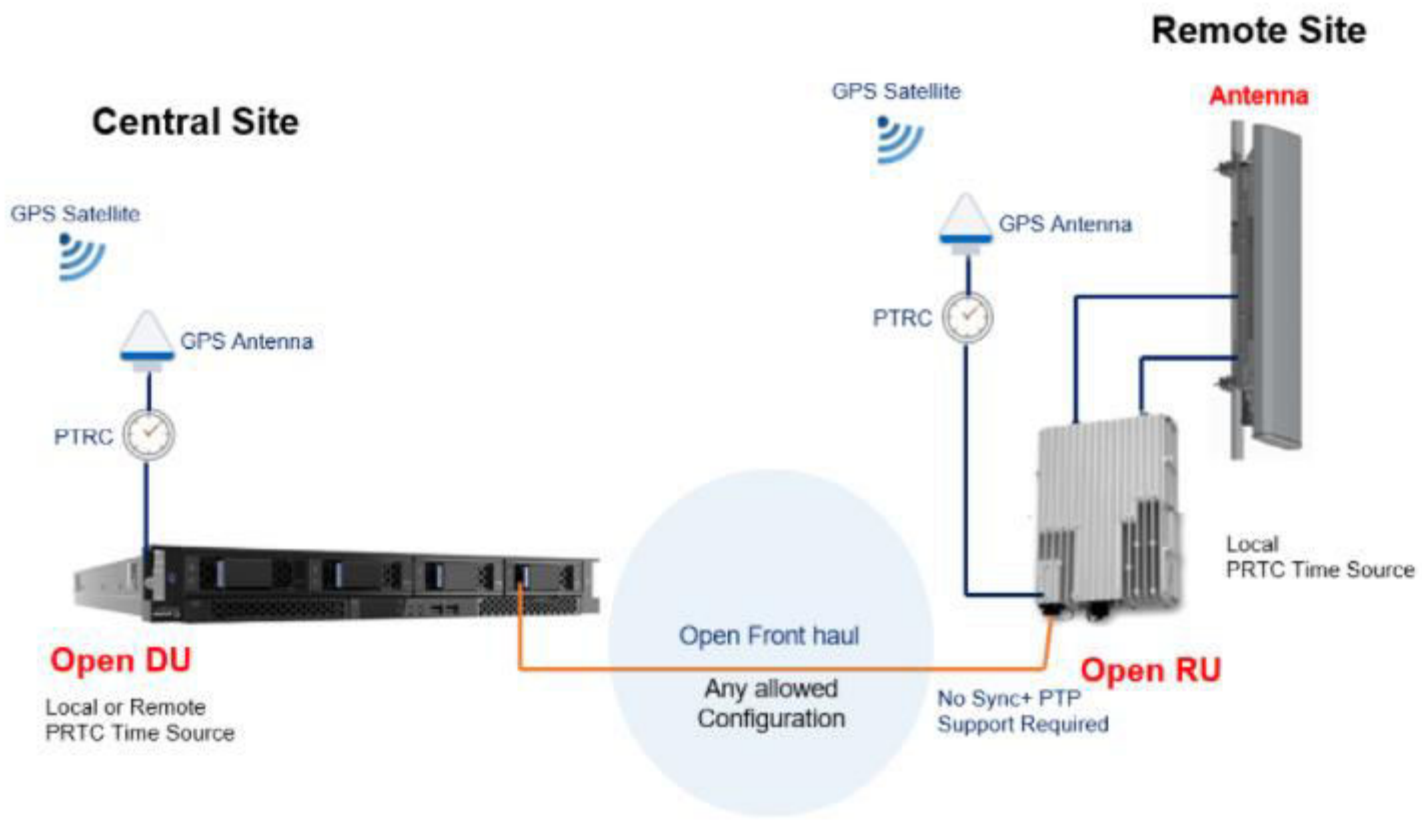
Open RAN- Sincronismo en el Fronthaul

Configuration LLS-C4 use a local PRTC (typically a GNSS receiver) providing the timing to O-RU and does not depend on fronthaul for timing and sync. Such configuration timing support at O-RU requires extra timing interface or embedded circuit within O-RU which may increase cost.



Open RAN- infraestructura

Qualcomm Summit 20 mayo 2021.

ANEXOS

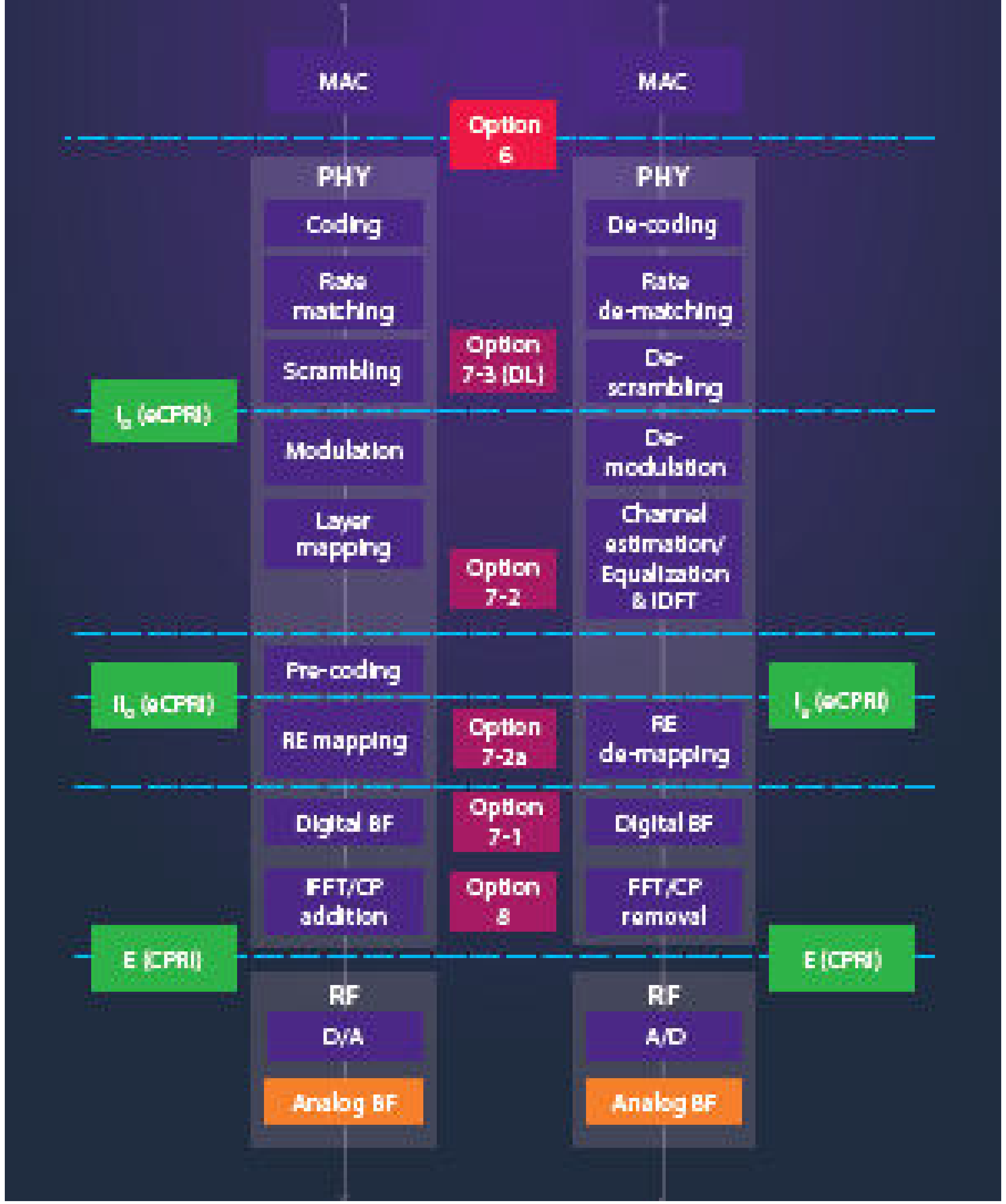
CALCULO DE ANCHO DE BANDA CPRI

$$BW_{CPRI} = N_S * N_{ANT} * R_S * 2N_{Res} * O_{CW} * O_{LC}$$

Ns: Numero de sectores
N_{ANT}: Número de elementos MIMO por sector
R_S: Tasa de muestreo. 15.36MHz para 10MHz
N_{Res}: Número de bits por muestra (Tipicamente 15 bits por muestra para LTE para eficiencia de capacidad). El 2 es por tener 2 muestras que se procesan en paralelo (I&Q)
O_{CW}: Respresenta el overhead introducido por el Control Word de CPRI (16/15: 1 control Word por cada 15 words de payload)
O_{LC}: Representa la codificación utilizada en función del modo CPRI (Puede ser 8B/10B, es decir 10 bit por cada 8 bits, lo que a su vez representa la relación 10/8 o se puede utilizar la codificación 64b/66b lo que representa la relación 66/64.

Considerando 10 MHz, Mimo 32T/32R (64), el ancho de banda requerido por CPRI resulta de 32 Gbps, Es decir mas de lo que soporta el protocolo CPRI.

Open RAN- Detalle de Capa física



Fronthaul en Open RAN, eCPRI

Ethernet based fronthaul

- Point to multipoint, no dependencia de F.Oscura.
- Soporte de Ethernet protocol stack.
- Reducción del ancho de banda requerido a través de la optimización de Split (split 7 en lugar de split 8)
- Resuelve los problemas de interoperabilidad en despiegues multi-vendor.

El objetivo de usar eCPRI en reemplazo de CPRI es disminuir las demandas de velocidad de datos entre el eREC y el eRE a través de una descomposición funcional, al tiempo que se limita la complejidad del eRE. Además, eCPRI está diseñado para permitir una transmisión de datos de radio eficiente y flexible a través de una red de transporte fronthaul basada en paquetes como IP o Ethernet.

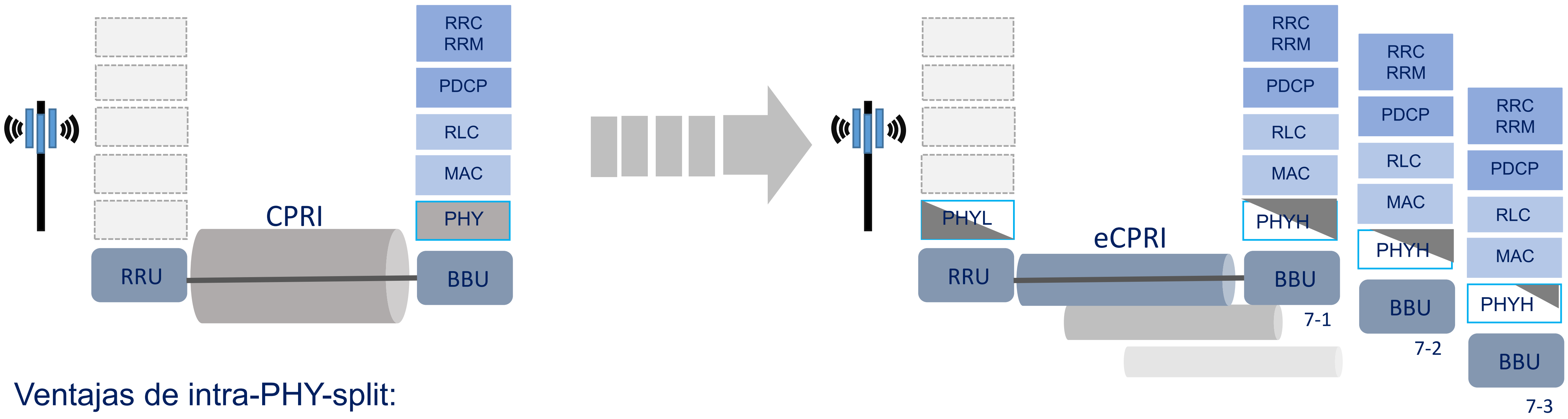
eCPRI debe ser usado entre las DU y RRU donde sea soportado.
Diferentes arquitecturas son posibles, incluyendo casos donde **RIU: Remote Interface Unit** debe ser usada como IOT con las RRU que no soportan eCPRI.

El modelo convencional de FH en 4G, separa la RF del resto de las capas L1/L2/L3 usando el protocol CPRI/OBSAI (option 8 split point). Esto permite la centralización de las capas altas a expensas de requerimientos de latencia y ancho de banda mas altos no compatibles ni con eMBB ni con URLL.

Fronthaul en Open RAN, eCPRI

El split de la capa física

Mientras que la descomposición functional de CPRI pensada para E-UTRA corresponde al split "E" donde el RE contiene **solo RF**, eCPRI permite diferentes splits functionales entre RE y REC.



Ventajas de intra-PHY-split:

Algunos features como Carrier Aggregation, Network MIMO, Downlink CoMP, Uplink L1 Comp Joint Processing, se soportan mas eficientemente

Desventajas de intra-PHY-split:

Se require una red de fronthaul con "mayor" capacidad y **"menor"** latencia comparada con split mas altos (como split 2), pero respecto de CPRI no presenta esta desventaja

Requerimientos de Front Haul

Latencia
Siempre que se respete el Budget de Latencia de 100 µs , se deberé utilizar una red de transporte, a fin de rentabilizar el uso de la fibra

Sincronismo
Tanto la vDU como la RRU (o RIU si hubiera), deben soportar SyncE y PTP (1588). Estos nodos deben soportar sincronismo de fase de acuerdo al Standad 8275.1, es decir que todos los elementos de la cadena desde el T-GM hasta la propia vDU deberán ser boundary clocks.

Tanto la RRU como a vDU podrán recibir sincronismo de DCSG, el que actuaría como boundary clock obteniendo la sincronía de su red (T-GM) PTP/SyncE en una configuración tipo LLS-C3.

Alternatvamente, la RRU podrá recibir sincronismo a través de eCPRI desde la vDU, la cual deberá actuar como boundary clock

Detalle de Midhaul

ALTIOSTAR

- Midhaul: Vinculo entre la vDU y la vCU
- Latencia: < 50ms (4G) / 2-3 Ms (5G)
- Jitter: < 3ms
- Packet Loss: < 2 x 10^{-4}
- Transport Media: Layer 3 (any Ethernet based medium)
- Capacidad: 3 a 10Gbps

➢ Layer 3 transport network

➢ Peak THP per sector ~380Mbps + 20% overhead
  - ❖ 3 Sectors DU could forward up to 1.37 Gbps
  - ❖ 6 Sectors vDU could forward up to 2.74 Gbps

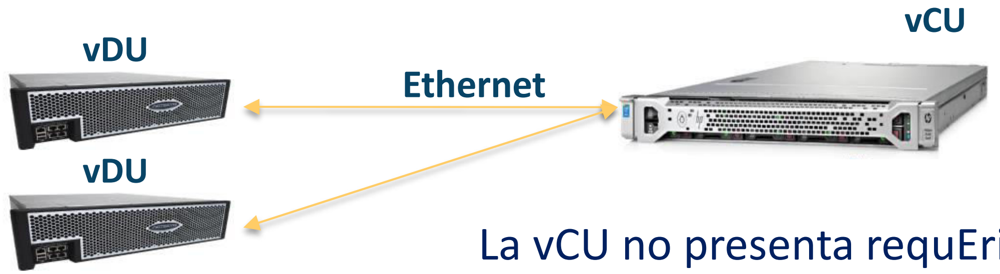
➢ vCU supports up to 12 sectors (e.g. 2 vDUs or 4 DUs).

➢ Maximum THP per vCU could reach up to 5.47 Gbps.

➢ Traffic will be statistically aggregated

Fuente: Altiostar

MIDHAUL



La vCU no presenta requErimientos críticos de sincronismo. Puede sincronizarse mediante NTP..

Arquitectura de HW O-RAN 4G/ 5G

Posibles Tópicos a Considerar

- Arquitectura / diseño de HW de cada tipo de Instalación (ePC / CU /DU / Site)
- Middleware para DU &CU, NFV & Contenedores
- Tipo de servidores (con o sin aceleración; con o sin SmartNIC)
- Conectividad y Sincronismo (IEEE-1588 v2 and Synchronous Ethernet).
- Elementos de conectividad (tipo nodo, interfaces, etc)
- Escala: Cantidad de Cores por tecnología, ancho de banda, y sitios
- Tipos de NIC
- Diseño de RU
- Disaggregated Cell Site Gateways (DCSG) para 4G/5G
- Integración al Core ePC, ePC+, 5GC

REDES DE QUINTA GENERACIÓN
Curso Nivel 2
Módulo 5 & 6

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TEMARIO

MODULO 1
La evolución histórica de las redes móviles. 2G/3G/4G.
Rol de 3GPP en la standarización.
Redes 4: LTE y EPC.
Conceptos heredados de LTE. Conceptos específicos de 5G.

MODULO 2
Motivadores para el despliegue de una red 5G. Por dónde empezar.
Concepto de Dual Connectivity.
Los terminales: Bandas, road map, chipsets. Impacto en la estrategia de despliegue.
La red de Acceso: Bandas, aspectos de propagación, ancho de banda.
El Núcleo: arquitectura a alto nivel.

MODULO 3
Arquitectura NSA. Visión de alto nivel.
Opciones de interconexión.
Planificación de red 5G inicial. Casos de uso.
DSS.Conceptos, posibles aplicaciones.

MODULO 4
Arquitectura SA. Visión de alto nivel.
Principales Desafíos de SA..
Impacto de 5G en IMS y servicios de tiempo real.

LTE & EPC

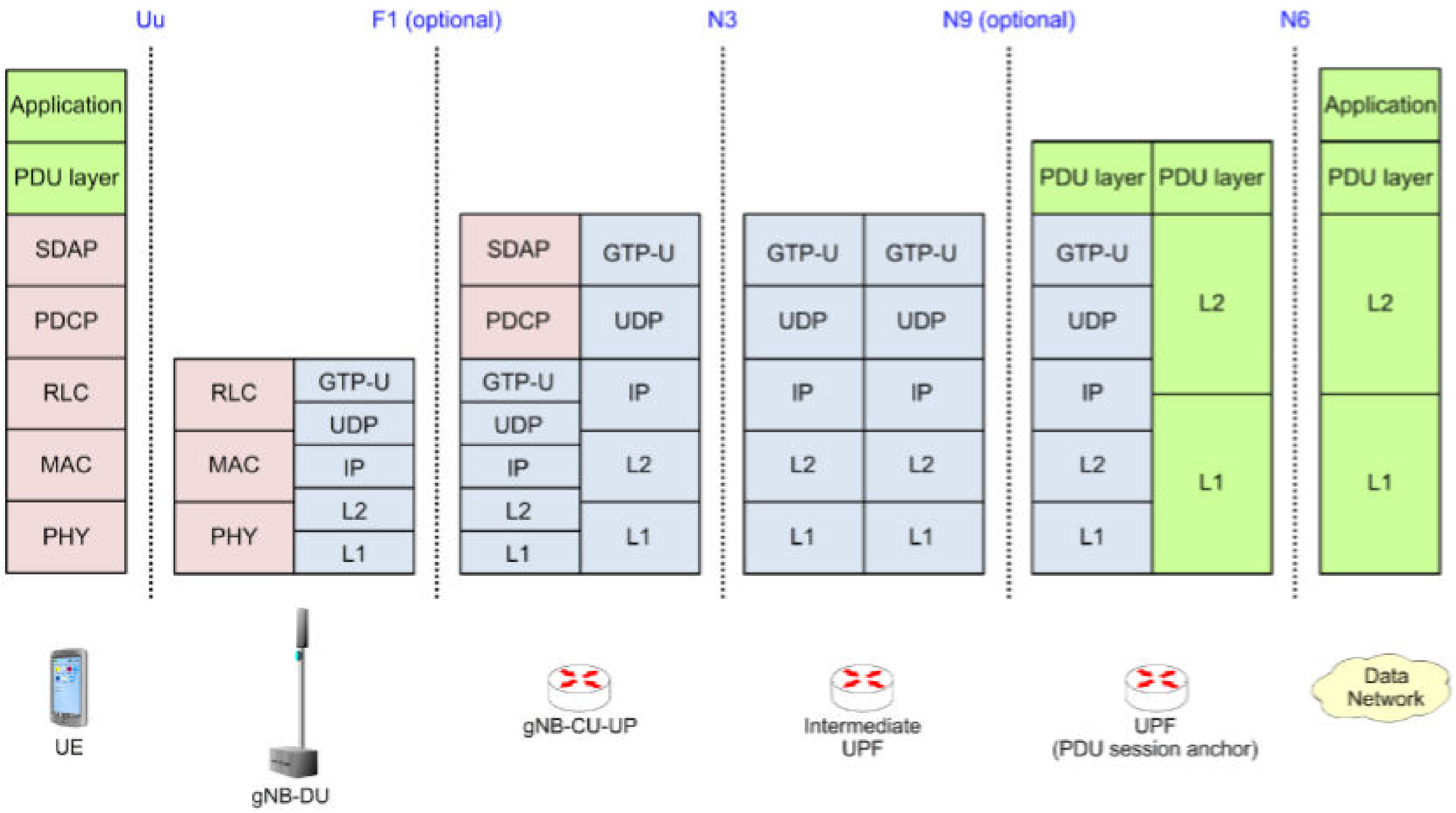
TEMARIO

MODULO 5
5G Signalling
NWDAF Network Data Analytics Function
SEPP Seurity Edge Protection Proxy

MODULO 6
Automatización
SDN
SON
RIC

RESUMEN CORE Y ACCESO

5G USER PLANE PROTOCOL STACK



La interfaz F1 es un caso especial no siempre implementado

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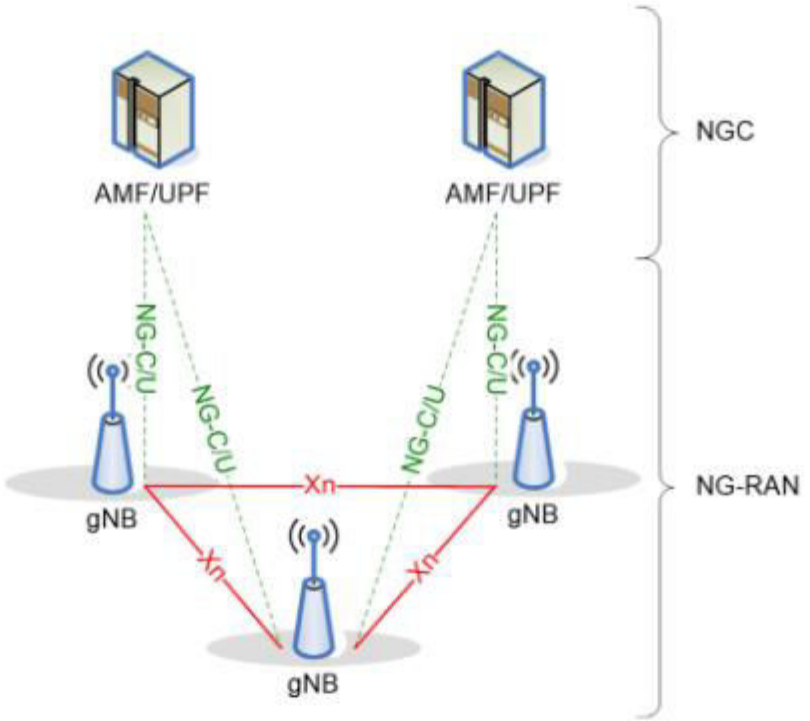
5G STANDALONE NETWORKING

PLANO DE CONTROL



En un escenario de 5G networking, el core cambia radicalmente si se lo compara con el EPC.
En la definición del NGC, el networking 5G tiene las siguientes características:

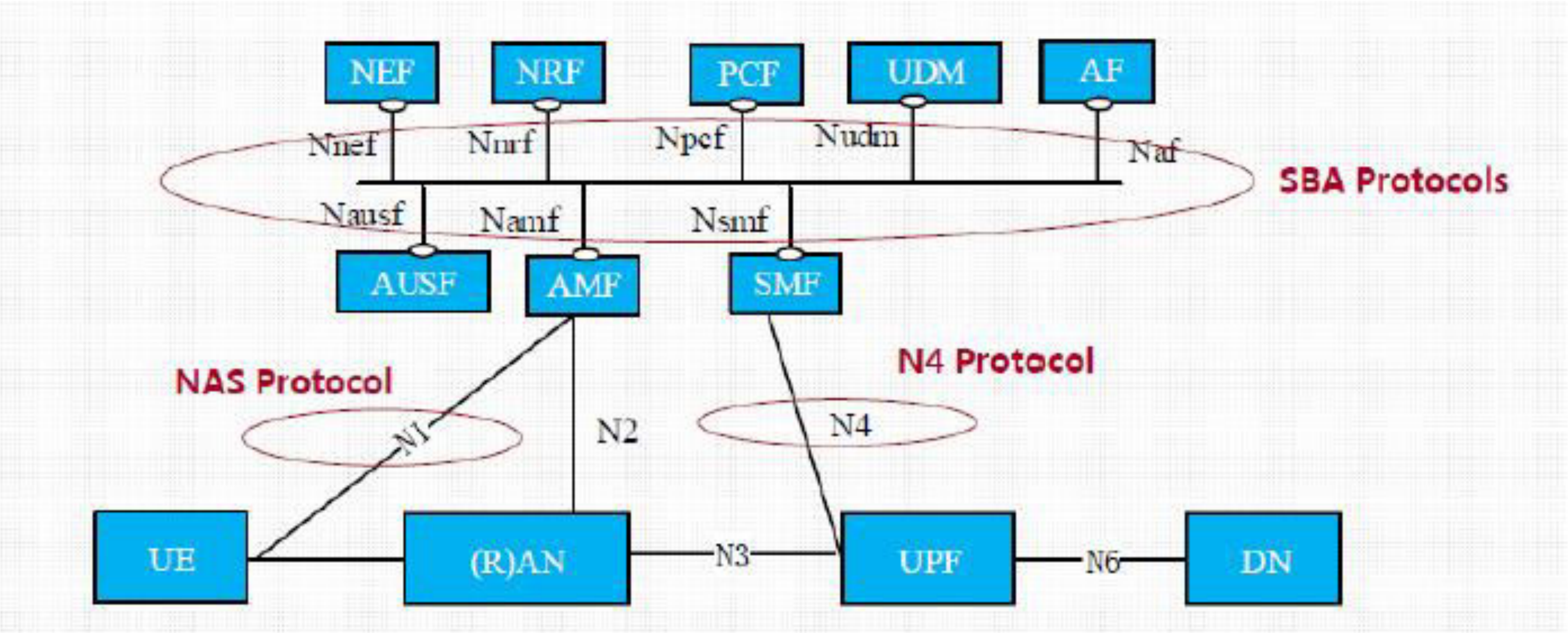
- La red usa tecnologías de virtualización NFV y SDN (también Contenedores), para desacoplar las funciones lógicas de HW

- Basandose en la arquitectura EPC se hace una separación profunda entre User plane y Control Plane

- Diseño modular de las funciones lógicas, Implementando Network Slicing

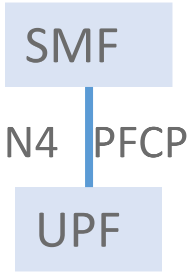
PROTOCOLOS

SBA architecture is moving to a Service Oriented Architecture (SOA) approach where control functions will communicate via HTTP 2.0 and APIs based on YAML (Yet another marking Languaje) and JSON (Java Script Object Notation).



PROTOCOLOS

N4 protocols. N4 is the interface binding the control plane and user plane of the 5G packet gateway. 3GPP defines the usage of the Packet Forwarding Control Protocol (PFCP) for the communication between the control and user plane elements affected by CUPS (Control and User Plane Separation).
In addition, it is planned to reuse PFCP, with some enhancements, in the interface N4. The user plane is done via extension of GTP U (over UDP).



Ref.: TS 29.244
PFCP's scope is similar to that of Open Flow, however it was engineered to serve the particular use-case of Mobile Core Networks.
PFCP is also used on the interface between the control plane and user plane functions of a disaggregated BNG, as defined by the Broadband Forum in TR-459

PFCP es usado en las interfaces Sxa, Exb, y Sxc (ePC+ CUPS)
PFCP es usado en la interfaz N4 en 5GC

PROTOCOLOS

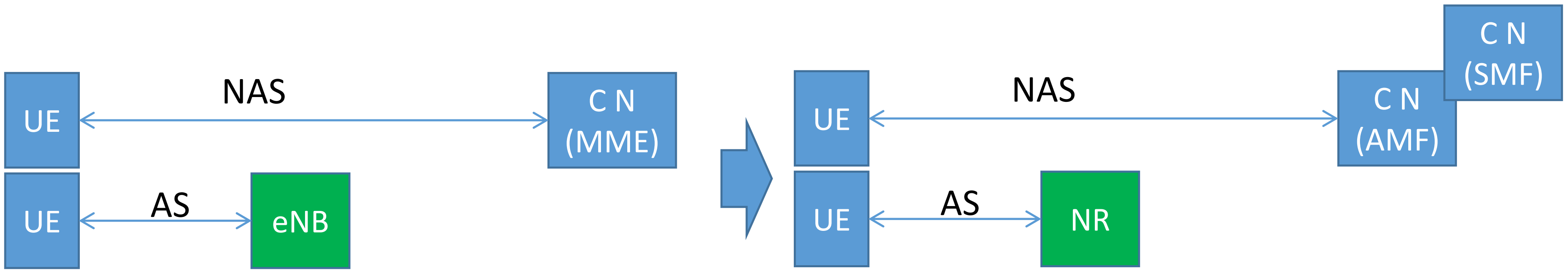
SBA architecture is moving to a Service Oriented Architecture (SOA) approach where control functions will communicate via HTTP 2.0 and APIs based on YAML (Yet another marking Languaje) and Json (Java Script Object Notation).

Key Issue	Selected Protocol
Architecture Style	Restful
Interface Definition Language	OpenAPI 3.0.0
Serialization Protocol	JSON
Application Layer Protocol	HTTP 2.0
Transport Layer Protocol	TCP

SBA Protocols: Are based on RESTFUL (Representational state transfer) APIS. Transport is still TCP.
QUIC (Quick UDP Internet Connections) usage is left for study in Rel 16.

PROTOCOLOS

NAS PROTOCOLS: NAS handles the UE access to the network



NAS over EAP-5G

NAS over PPOE

NAS over IP

5G CORE NETWORK PROTOCOLS- 3GPP EVOLUTION

Aligned with Virtualisation & Uses a Service Based Architecture

Example: "Update Location"

ISUP/MAP/INAP
TCAP
SCCP
MTP3
MTP2
MTP1
Stack SN7

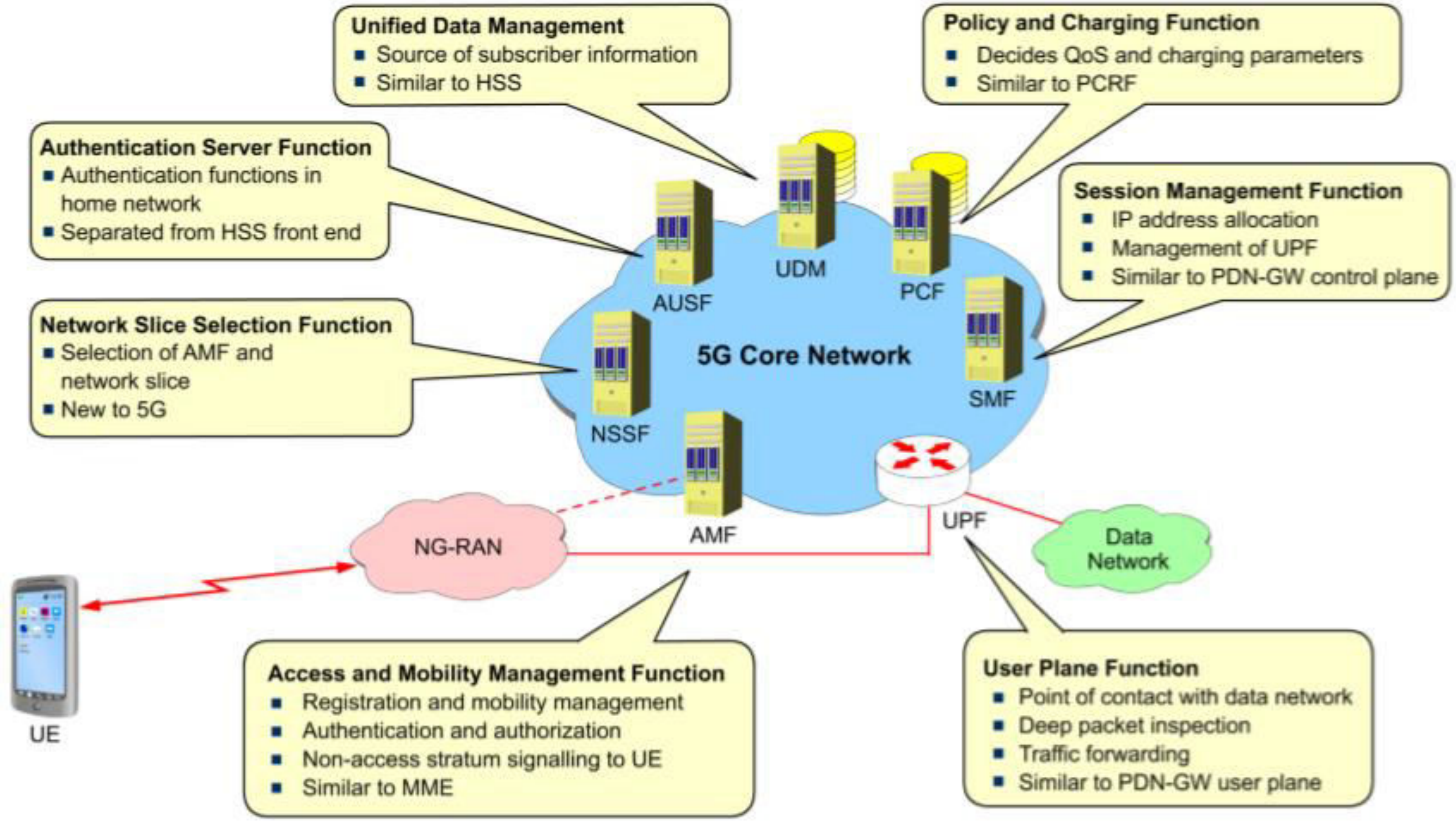
	2G	3G	4G	5G
	Update Location	Update Location	Update Location	Update Location
	MAP	MAP	S6a	N8 / JSON
	TCAP	TCAP	Diameter	HTTP/2
	SCCP	SCCP	SCTP	TCP
	MTP	SIGTRAN	IP	IP
	Stack SN7		IP based	

SEÑALIZ APP	DIAMETER /HTTP2
TRANSPORTE	SCTP/ TCP
RED	IP
ENLACE	ENLACE
FÍSICA	FÍSICA

IP based

La interfaz F1 es un caso especial no siempre implementado

MAPEO DE FUNCIONES DE EPC EN NGC



ENTIDADES DE NGC

AMF Access and Mobility Management Function. Which is an enhancement of the current MME able to perform dynamic selection of slicing and packet data gateway for use cases associated to MEC (mobile Edge Computing).
SMF. Session Management Function. The PGW is split in UPF (user plane) and SMF (control plane). SMF will be able to perform dynamic UPF selection for supporting the MEC concept.
NRF Network Repository Function. By adopting a service oriented architecture new discovery and authorization capability is required for the different module to access each other.
AUSF Authentication Server Function. New authentication functions used in order to support non SIM based devices.
NSSF. Network slicing selection function. Required in order to enhanced slice selection
UDM Unified Data Management. Stores subscriber data and profiles. Similar to an HSS in 4G, but will be used for both fixed and mobile access in 5G Core.
UDR: User Data Repository
PCF Policy Control function. Provides a policy framework incorporating network slicing, roaming and mobility management. Equivalent to PCRF in 4G
UPF : User plane Function.
DN : Data network.
SDSF: Structured Data Storage Network Function .
UDSF: Unstructured Data Storage network function.
AF : Application Function.

5G SYSTEM (5GS)

UE

UE

UE

UE

ACCESS NETWORK

NG-RAN

gNB

gNB

AP

- New Radio (NR)
- Combined NR and LTE
  - non.-standalone NR
  - Initially with EPC
- LTE (evolved)
- ….combined with WIFI

NON-3GPP Access Network

AP

- Non-3GPP access
  - un-trusted non 3GPP access
  - eg. Home WIFI and fixed BB

5G CORE NETWORK (5GC)

NSSF UDM NEF

AMF SMF PCF

- Storage of subscriber data
- Registration &authentication
- Mobiliy Management
- Reachability Mgmnt
- Session Management
- Policy Control
- Capabilities Exposure (to DNs)
- User Data Transfer

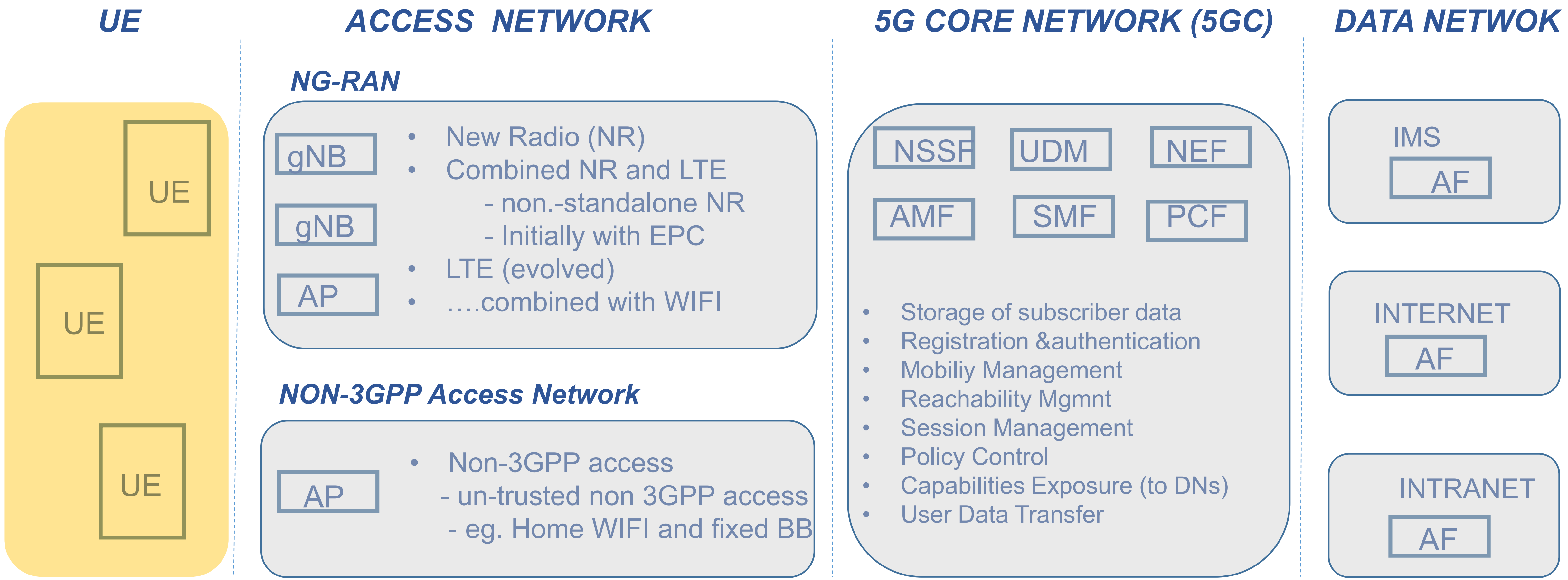
DATA NETWOK

IMS
AF

INTERNET
AF

INTRANET
AF

5G SYSTEM (5GS)



- **Smartphones**
- **Pads/tables**
- **“Things”/Gateways**
- **“5G Router” (FWA)**

Smartphones

- Very mobile
- Lots of data
- eMBB

Meters

- Stationary
- Not much data
- mMTC

Vehicle to X

- May be critical
- Possible D2D
- URLLC

5G SYSTEM (5GS)

UE

UE

UE

UE

ACCESS NETWORK

NG-RAN

gNB

gNB

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- Capabilities Exposure (to DNs)
- User Data Transfer

DATA NETWOK

IMS
AF

INTERNET
AF

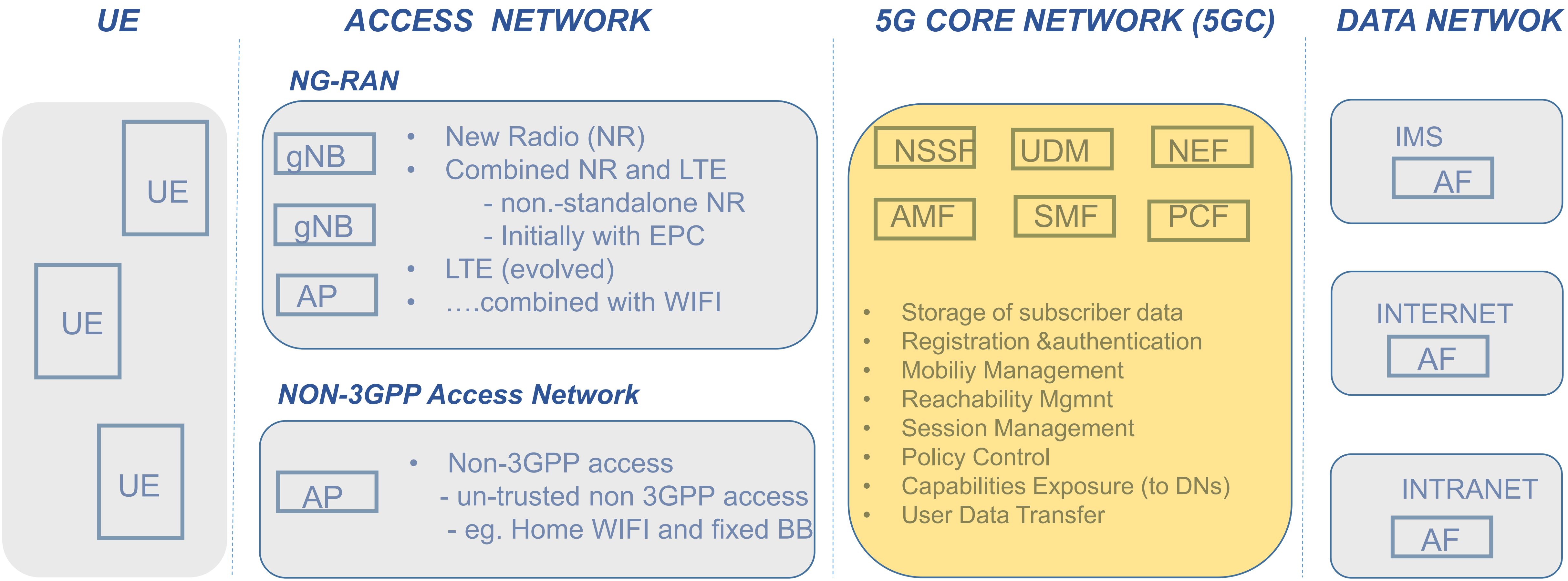
INTRANET
AF

NG-RAN Features

- New frecuency spectrum
  -Traditional fq ranges (<6 GHz)
  - High: 6- 100 GHz fq-bands
- Use of unlicensed spectrum (LAA)

- New Radio (NR), still OFDM
- Carrier Aggregation, Massive MIMO
- Tight integration with E-UTRA (e.g Dual Connectivity)
- Integration with WIFI (LWA)

5G SYSTEM (5GS)



5G Core Features

- VNFs in Central and Distributed Data Centers
- Clear Separation of CP and UP functions (CUPS)
- Closer integration with Network possible
- More flexibe UP paths
- Service-Based architecture

NWDAF

NWDAF: Network Data Analytics Function

NWDAF: Network Data Analytics Function, just another NF!!!
Just another NF??????

¿What is the Network Data Analytics Function?
Network Operators have allways needed to collect data from their networks in order to evaluate the performance of each node/function deployed.
During the days of PSTN and SS7 networks, also during the days of 2G and 3G , when the networks were mostly TDMA based, it was easier to monitor the performance of the nework through some indicators (“KPI”: Key Performance Indicators) in comparison with current networks today.

As the network became more complex, new type of analytic solutions were developed. Most of them were propietary solutions, run over propietarry HW, in summary another “silo” in the network.

With the deployment of 4G solutions, the usage of Artificial intelligence (AI) alghoritms and machine learning (ML) were introduced in order to do predictive analytics, fault detection, trend analysis, etc.

At the same time, new use cases as user experience, personalized marketing, data monetization, among others, arised

5G network, both, the RAN and also the 5GC are more complex than their predecessors, the number of “NF” in 5G Core is constantly increasing what means that new and more powerful Analytics tools are needed

NWDAF: Network Data Analytics Function, just another NF!!!
Just another NF??????

The challenge that Operators usually face is related TO some of following topics:

-Different Network providers
-Different solution for data collecting (probes)
-Different formats
-Lack of interoperability and inconsistences among the different systems

New Analytic tools should help Operators:

-To know what has happened (statistical data)
-To know what is happening right now (real time or near real time input and autonomous reaction)
-To know what is going to happen (prediction and non real time solutions)

NWDAF: Network Data Analytics Function, just another NF!!!
Just another NF??????

Network Data Analytics Function is going to be key piece within the SBA. It will be mandatory in analytic and automation of 5G networks.

"NF“NWDAF was introduced in R15 but it was finally specified R16 and R17

NWDAF is a new NF defined by 3GPP within 5GC Architecture in TS 29.520. It provides Analytics Fucntions for the Network in order to make possible the automation and reporting

3GPP TS 29.520 V17.5.0 (2021-12)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Core Network and Terminals;
5G System; Network Data Analytics Services;
Stage 3
(Release 17)

A GLOBAL INITIATIVE

NWDAF: Network Data Analytics Function, just another NF!!!
Just another NF??????

As a 5GC NF, the NWDAF is a central piece in the Network, and must fullfil following requirements:

-To solve the current challenges of highly distributed and multi-vendor interfaces or formats and networks.

-To collect analyze and expose data.

-To Automate and optimize 5G network operations much more efficiently.

-To be cloud-native.

-Multi-vendor capable solution (it means that this "NF" should be deployed in any 5GC).

-Probeless solution.

-SaaS solution.

NWDAF: Network Data Analytics Function, just another NF!!!

Just another NF??????

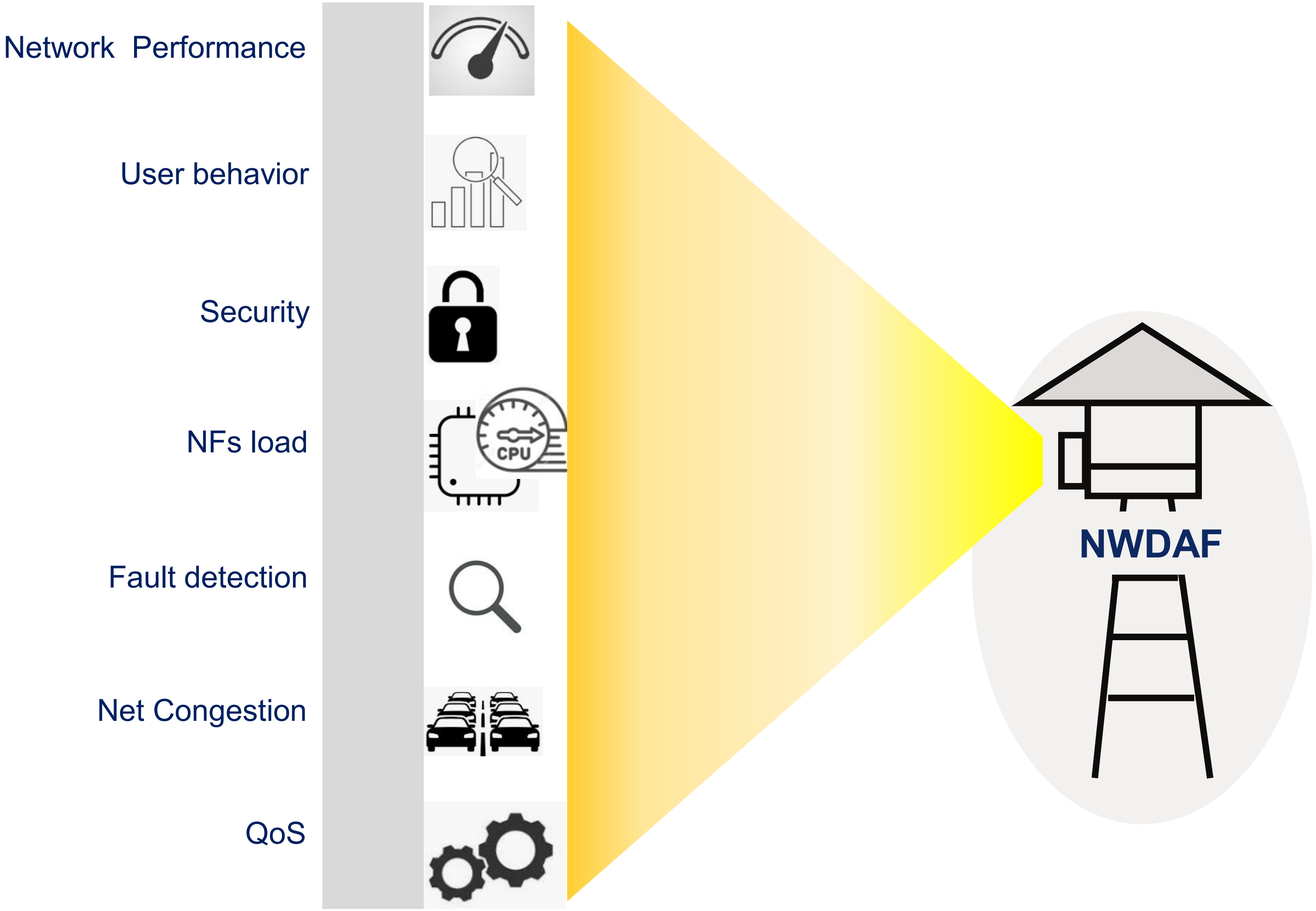
Software as a Service	Platform as a Service	Infrastructure as a Service
SaaS	**PaaS**	**IaaS**
Provides the framework and the apps	Provides the framework. User develop its apps	Provides the infrastructure (DC) We can develop VPN, Routers, etc

Why NWDAF

Data can have different users
Data can have different purpose
Data can procede from different sources and domains

- -MM, Mobility management
- -SM, session management
- -QoS, QoS management
- -Security Management
- -Life cycle
- -Scale
- -Traffic steering

- •3GPP TS 23.288
- •3GPP TS 29.520
- •TR23791



WHAT IS NWDAF?

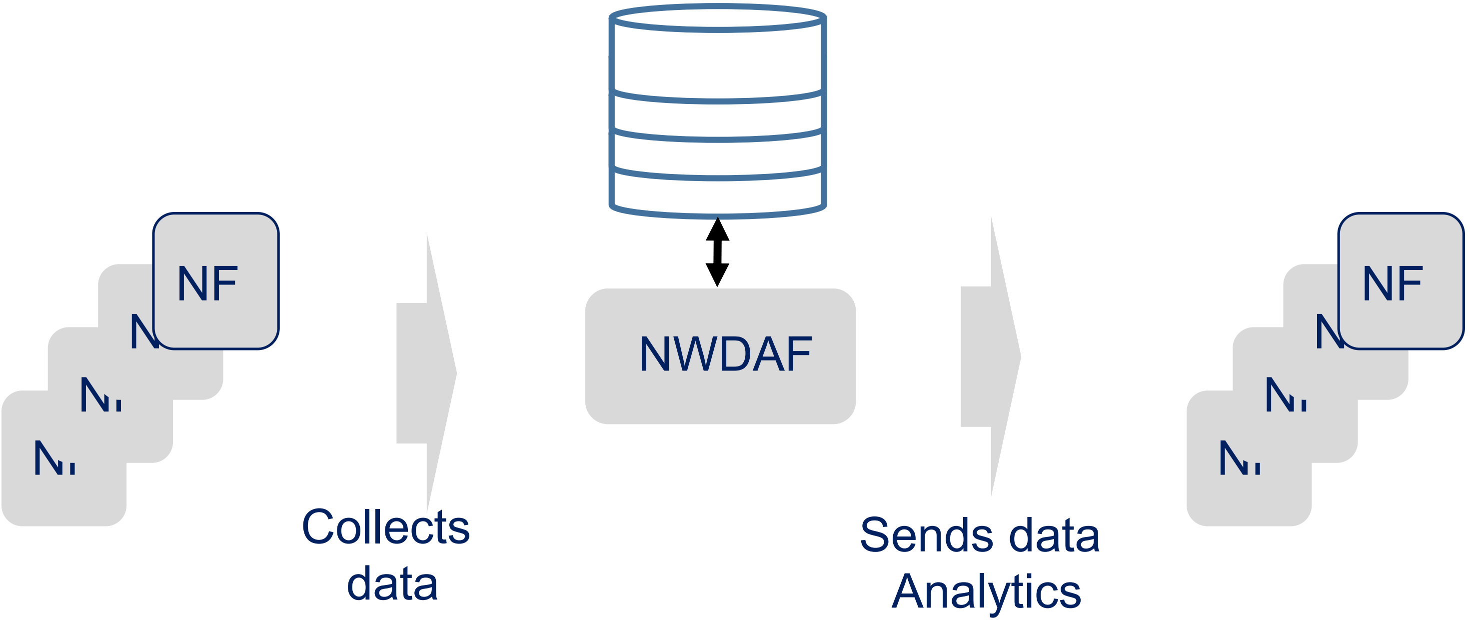
NWDAF (5GC), in such a way could be consireded analogous to **RIC** (RAN), but they are not exactly the same.

Anlike the RIC (RAN Intelligence Controller) introduced in OPEN RAN, which collect data from the Radio, expose those Data through open APIS and acts/impacts over the RAN, the NWDAF can collect, analyze and expose data, but does not modify any configuration of the network per se.

There can be other NF (or may be external users) which will be the “consumers” of those data

The 5GC should include open APIs (through NEF) for those external users, what means greather innovation and unlock new value (which is very similar to RIC).

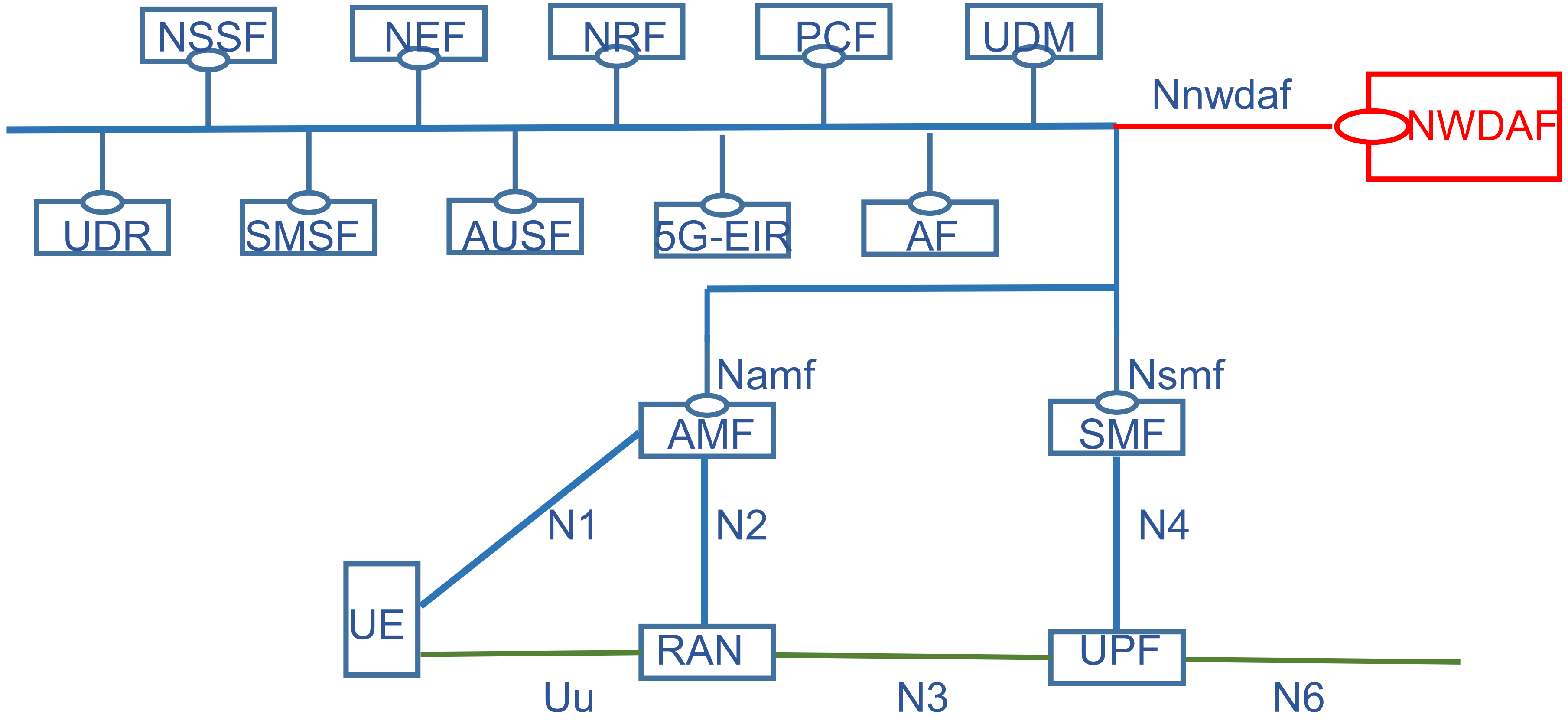
A distributed NWDAF architecture should also make analytics available where needed to meet the varying latency requirements of 5G use cases. Remember that some NF (UPF), could be located in the Edge which is closely related to Network Slice



NWDAF can be deployed as a **central NF**, as some distributed or **edge NFs** or as a combination of one central NF plus some edge NFs

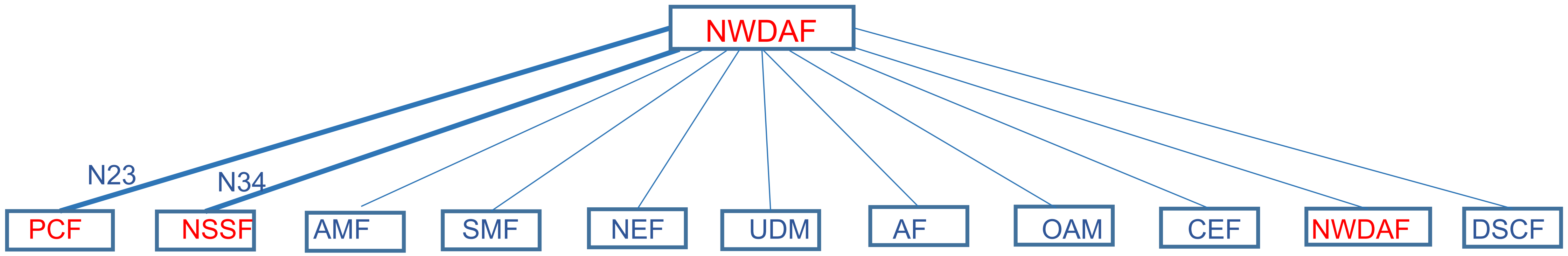
NWDAF ARCHITECTURE

Reference Architecture for the Nnwdaf_EventsSubscription Service; SBI representation



NWDAF ARCHITECTURE

Reference Architecture for the Nnwdaf_EventsSubscription Service; Reference point representation



SERVICES OFFERED BY THE NWDAF

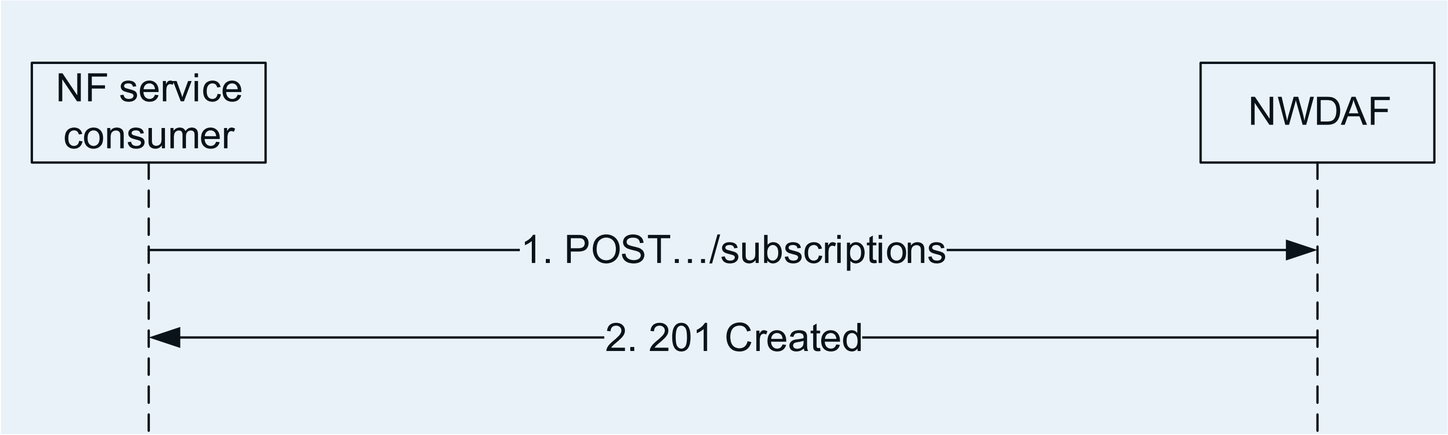
EVENT SUBSCRIPTION FOR ANALYTICS Nnwdaf_EventsSubscription	This service enables the NF service consumers to subscribe to/unsubscribe from notifications for different analytics information from the NWDAF. It also enables the transfer of subscriptions between NWDAFs
REQUEST AND GET ANALYTICS Nnwdaf_AnalyticsInfo	This service enables the NF service consumers to request and get specific analytics or context information related to analytics subscriptions from the NWDAF.
EVENT SUBSCRIPTION FOR EVENTS Nnwdaf_DataManagement	This service enables the NF service consumers to subscribe to/unsubscribe from notifications when subscribed event(s) are detected or retrieve the subscribed data from the NWDAF.
EVENT SUBSCRIPTION FOR NOTIFICATION MLNnwdaf_MLModelProvision	This service enables the NF service consumers to subscribe to/unsubscribe from notifications when a ML model matching the subscription parameters becomes available.

- 3GPP TS 23.288
- 3GPP TS 29.520
- TR23791

Based on point 4 of TS 29.520

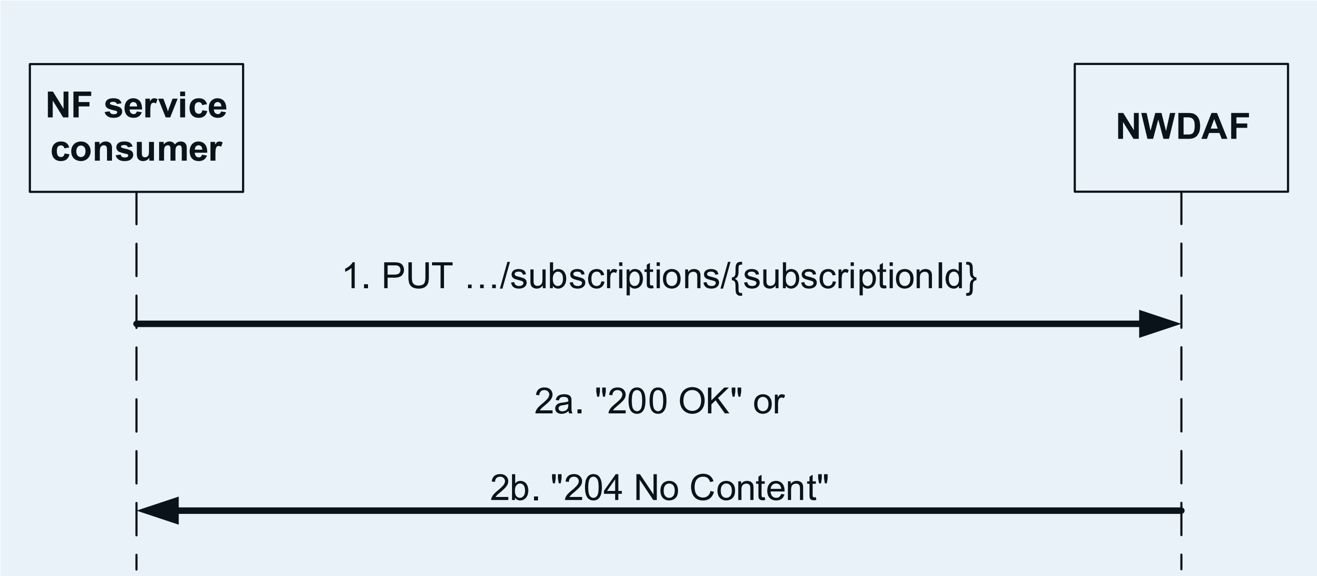
SERVICES OPERATIONS (EXAMPLE FOR Nnwdaf_EventsSubscription)

EVENT SUBSCRIPTION



Scenario where the NF service consumer sends a request to the NWDAF to **subscribe for event** notification(s)

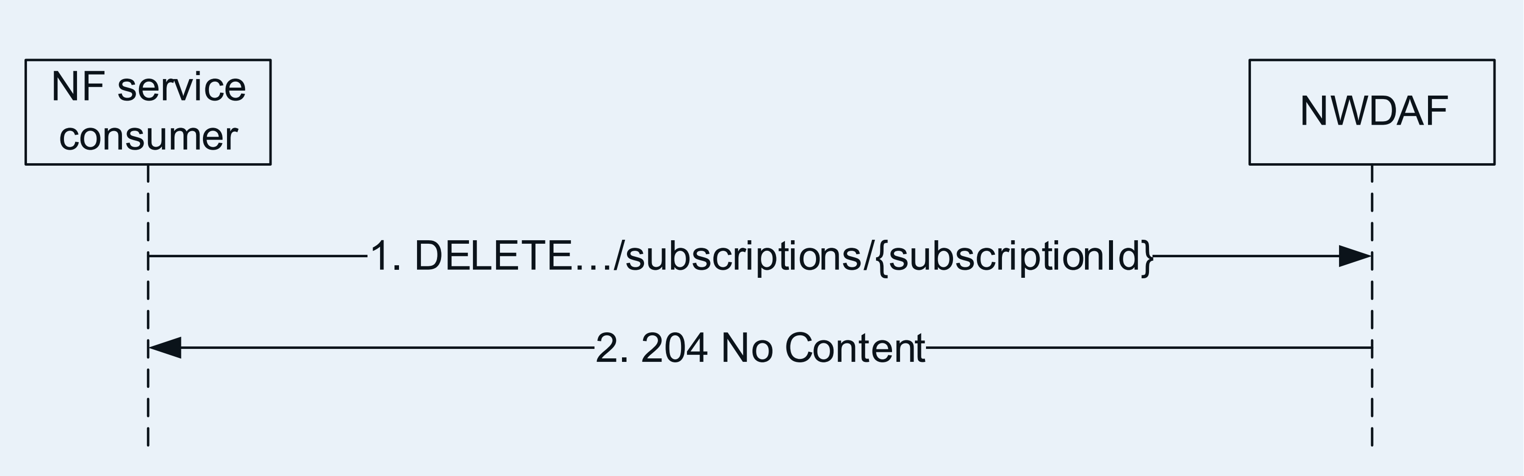
Scenario where the NF service consumer sends a request to the NWDAF to **update the subscription** for event notifications



Source: TS.29.520

SERVICES OPERATIONS (EXAMPLE FOR Nnwdaf_EventsSubscription)

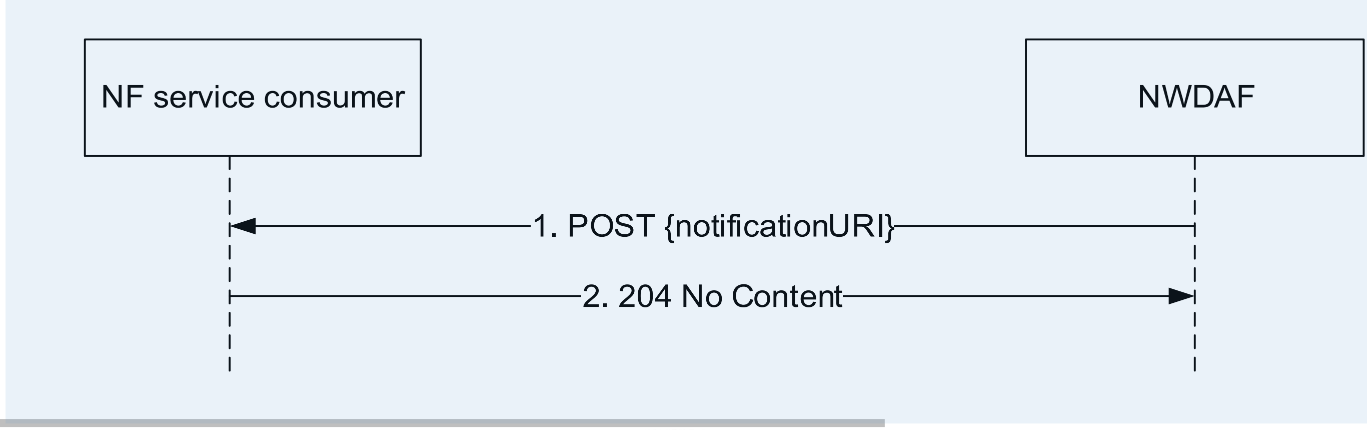
CANCEL EVENT SUBSCRIPTION



Scenario where the NF service consumer sends a request to the NWDAF to **unsubscribe from event** notifications (

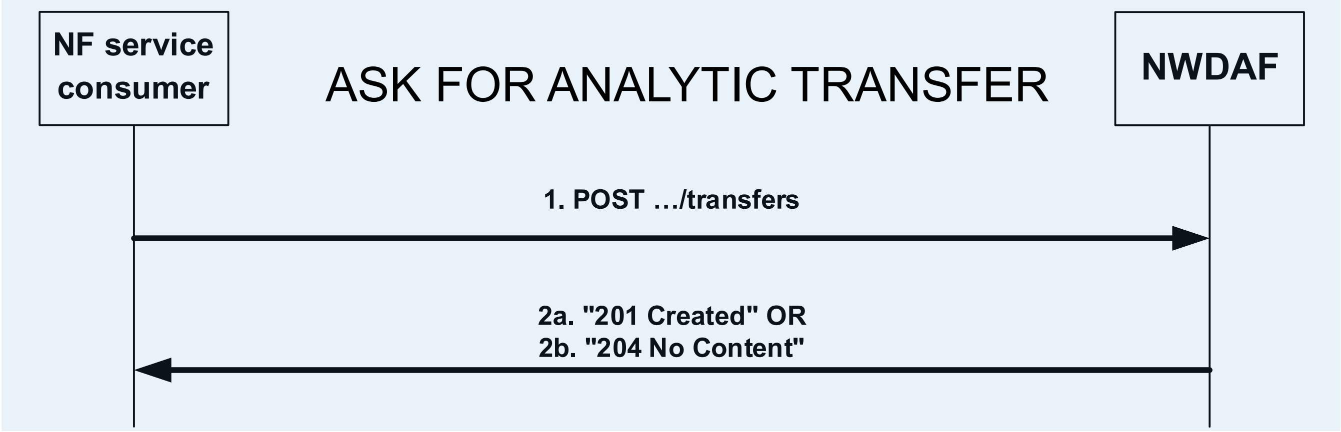
ASK FOR NOTIFICATION

Scenario where the NWDAF sends a request to the NF Service Consumer **to notify for event** notifications



Source: TS.29.520

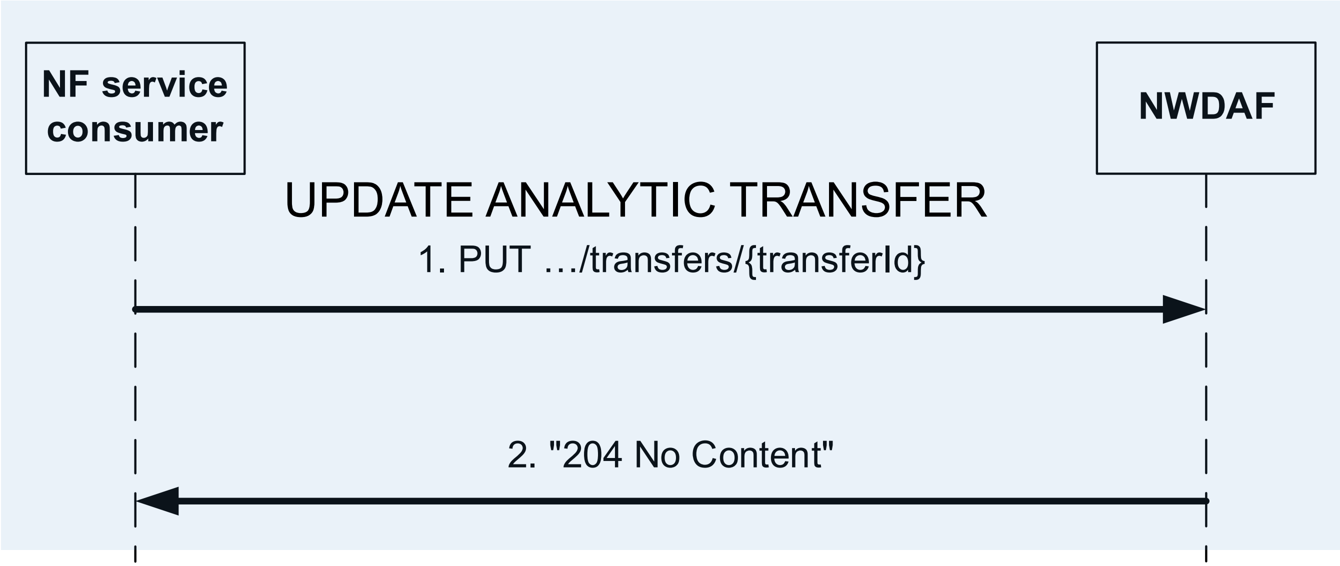
SERVICES OPERATIONS (EXAMPLE FOR Nnwdaf_EventsSubscription)



Scenario where the NF Service Consumer (e.g. NWDAF) sends a request to the NWDAF to request the **transfer of analytics** subscription(s) from the NF Service Consumer to the NF Service Producer

(From one NF to another NF)

Scenario where the NF Service Consumer (e.g. NWDAF) sends a request to the NWDAF to update a request for the transfer of analytics subscription(s) from the NF Service Consumer to the NF Service Producer



Source: TS.29.520

INTRODUCTION TO SDN

SDN. INTRODUCTION

- The Networks has not changed a lot in years, but SDN has been introduced recenty
- SDN networks introduces years ago, are the **most important paradigm shift** experienced in networks along 30 years.
- In Networking, unlike in other industries like SW programming, we have been using the same technologies during almost 30 years, without any changes

  Ethernet
  IP V4
  DNS
  DHCPs

  What is SDN?
  Huge change!!

Programmable infrastructure: Apply “programming code” to infra using programming Languages like JAVA.
Without SDN, the infra is rigid. Propietary Operating Systems, only some nodes can be modified

Centralized. Each infra parameter can be programmed in centralized way

Dynamic and fast optimization. As network grow, doing it manually is too complex

Automation. Network reacts as expected after events . It is executed in background

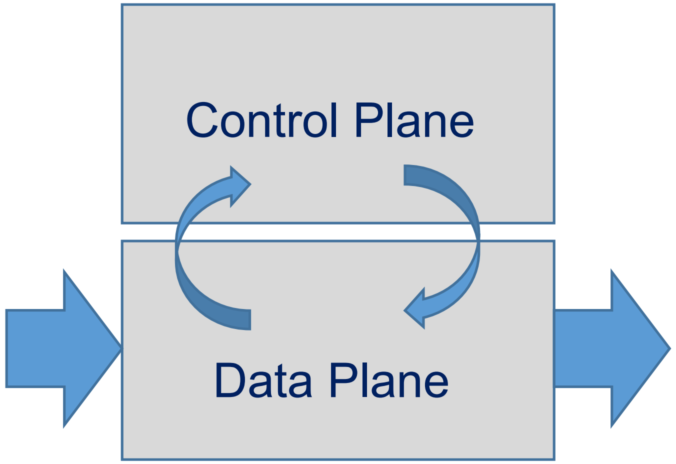
Off load the network device. SDN’s approach, which takes all overhead out of the devices, allows them to focus on what they are primarily built to do (forward data)

OPEN SOURCE. Not Vendor lock in. Interoperability.

SDN. COMPONENTS

Data plane asks Control plane what to do with a packet. Control Plane selects the interface. It is done for each device

Data Plane:
Physical or virtual
FIB (CEF),
Forwarding,

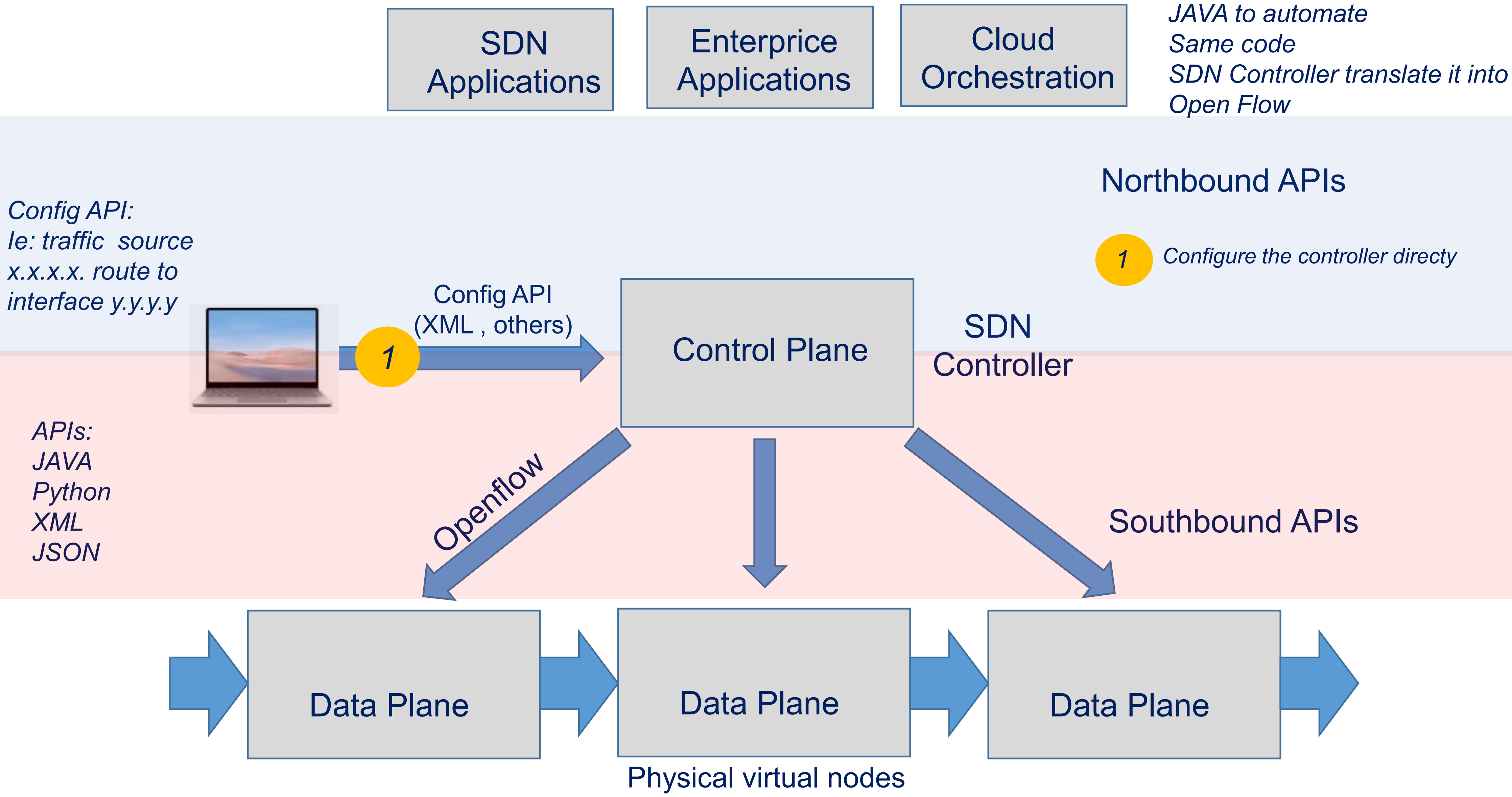


Control Plane:
Control functions
Routing policies
-Routing tables,
-Topology tables,
-ARP tables
-STP information,
-CAM table (switch)
etc

- Interfaz especif
- Broadcast
- Multicasl

CEF: Cisco Express Forwarding

SDN. COMPONENTS

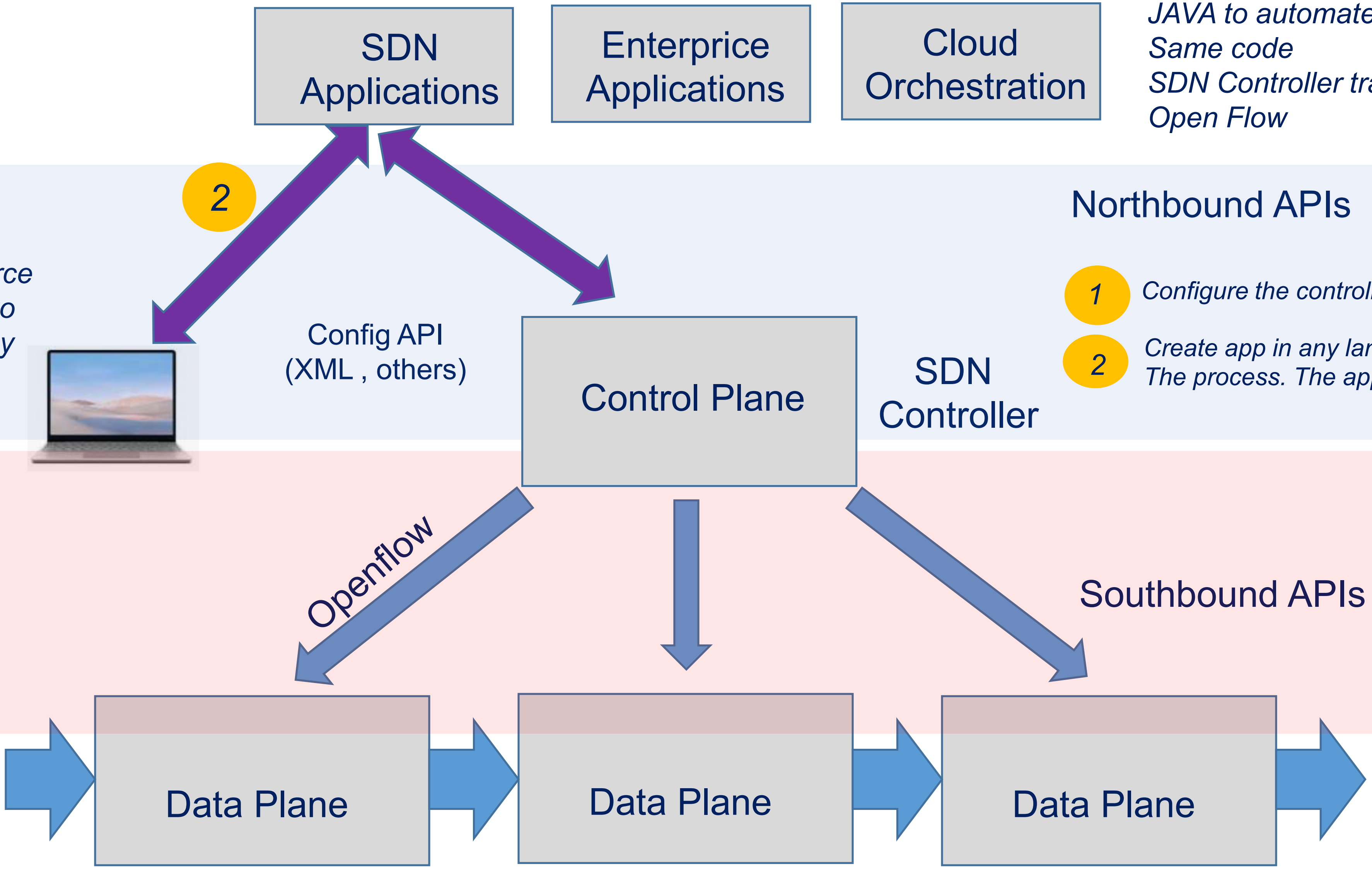


SDN. COMPONENTS

SDN Apps:
JAVA to automate
Same code
SDN Controller translate it into
Open Flow

Config API:
Ie: traffic source
x.x.x.x. route to
interface y.y.y.y

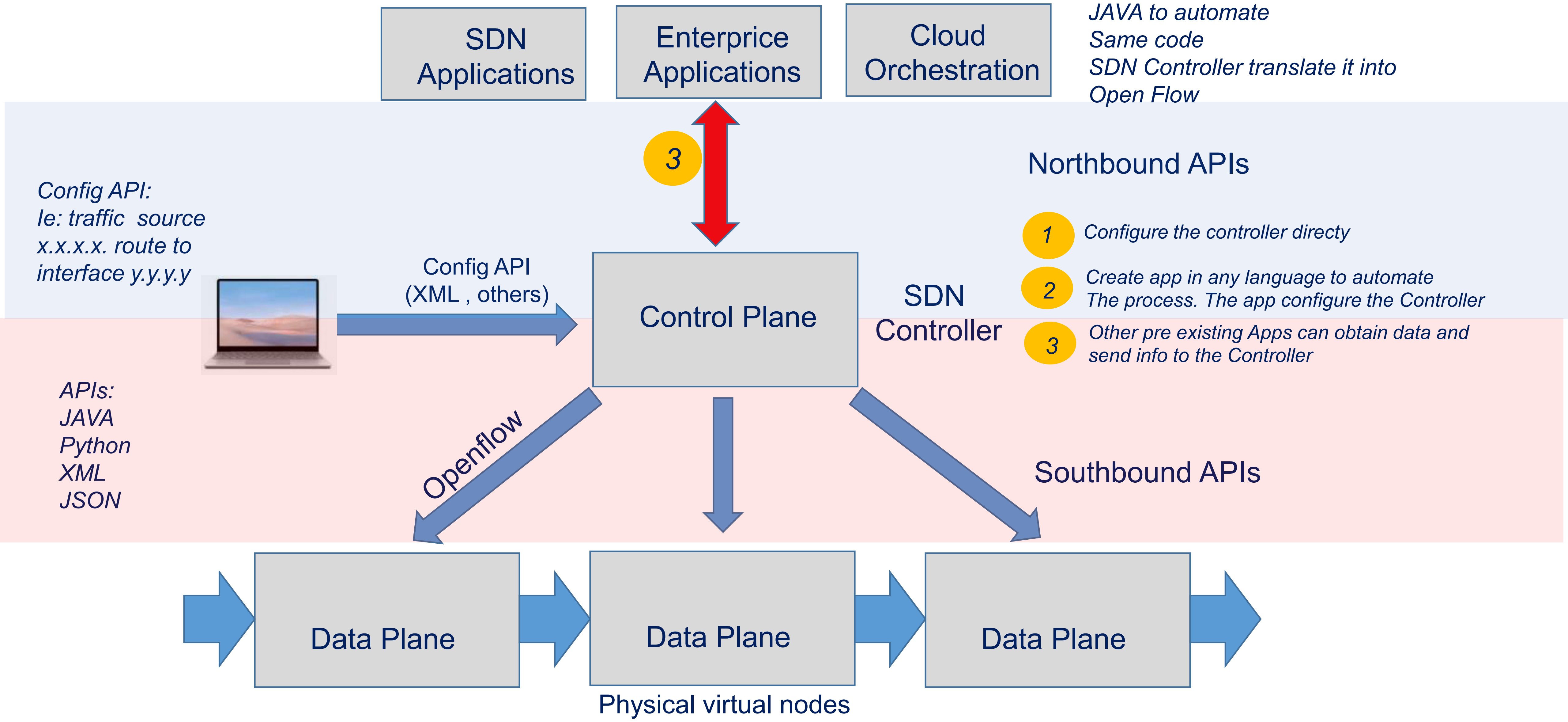
APIs:
JAVA
Python
XML
JSON



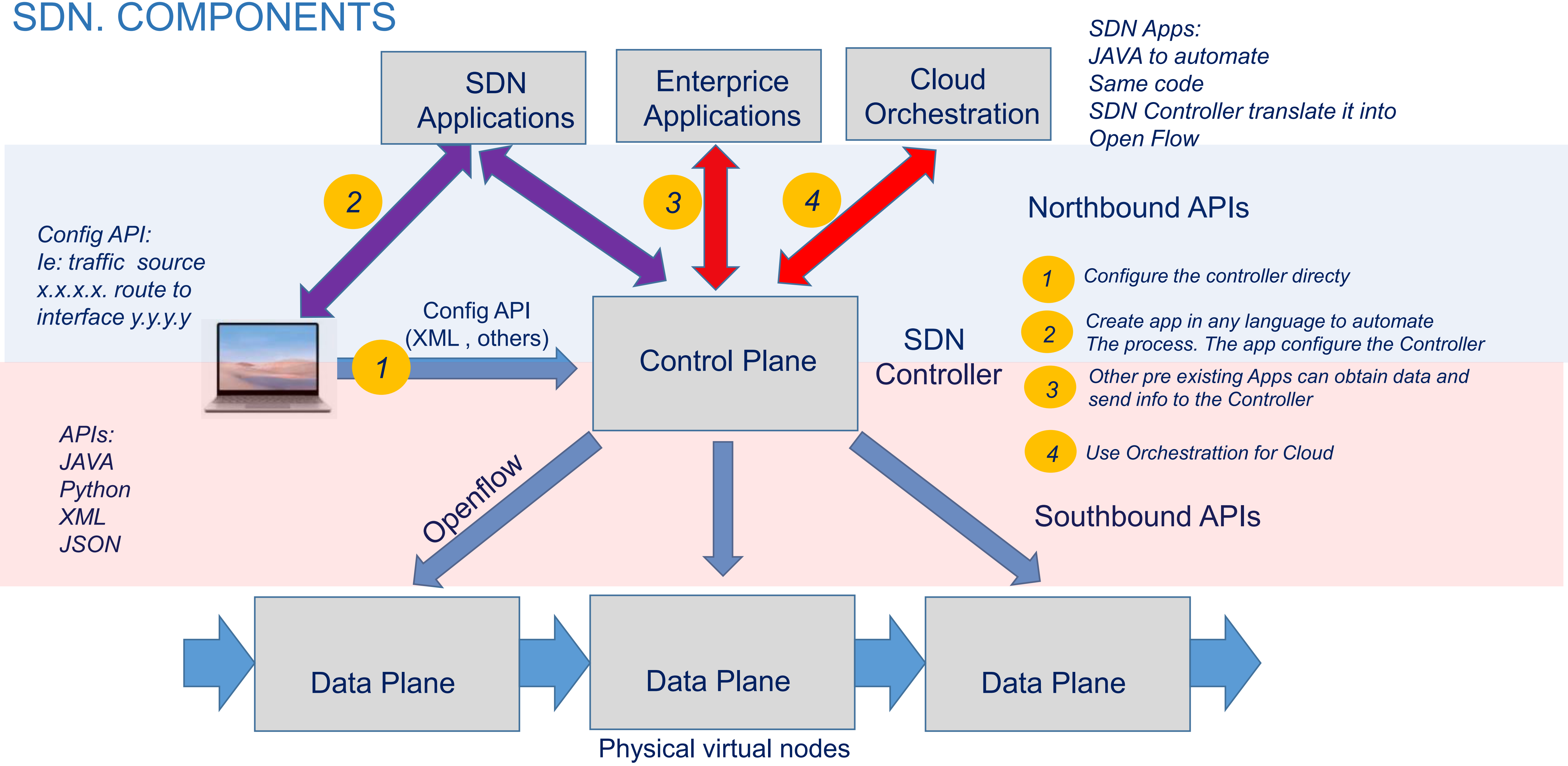
1 *Configure the controller directy*

2 *Create app in any language to automate The process. The app configure the Controller*

SDN. COMPONENTS



SDN. COMPONENTS



SDN. COMPONENTS. CP & DP

1 2 3 4

SDN Controller

Not all physical switches
Support Openflow

Openflow (TLS)

Mngmt network

SDN switch

Openflow Interface

Flow table 1

Flow table 2

Flow table n

Openflow over TLS

SDN SWITCH has N “Flow tables”
Each “Flow table” can have M “Flows”
Each table has diff type of instruction
If policy/instruction in flow M matchs , action is executed

The SDN controller (or controllers, if more than one is used) don’t have to be geographically collocated with the network devices, but they should **be able to communicate with the network devices** they are controlling. Various open source and commercial flavors of SDN controllers are available.

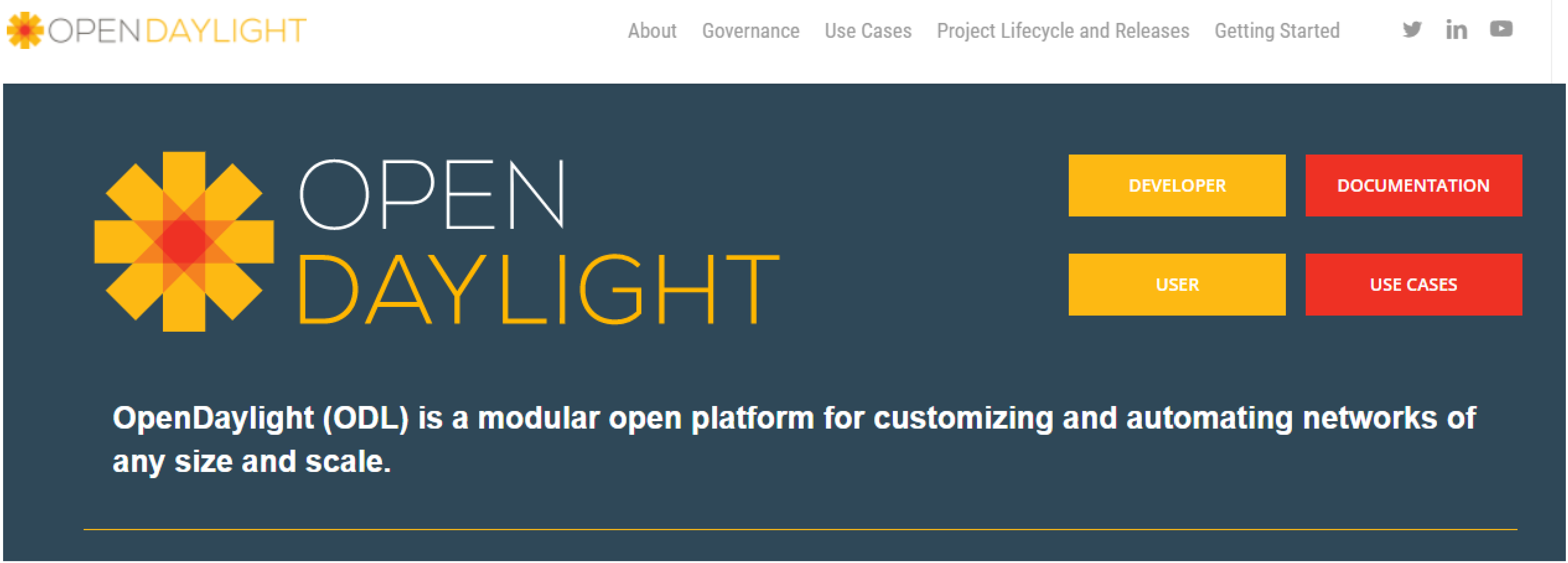
Ethernet Frame

DEST MAC	SRC MAC	DEST IP	SRC IP	TCP PORT	ACTION
Any	Any	00fe	Any	80	port 1
Any	Any	Any	10.0.0.2	80	port 3

Source
Destination
VLAN TAG
PRIORITY.
etc

SDN CONTROLLERS

go to opendaylight.org



SDN CONTROLLERS

source: opendaylight.org

The modern software-defined networking (SDN) movement grew out of a simple question: *why shouldn't networking devices be programmable just as other computing platforms are?*

The benefits of such an approach were obvious: no more arcane protocols to learn. No more waiting and hoping for networking vendors to develop specialized features you need. And if you could develop your own features, you could then optimize your device selection for price and performance independently of feature-richness.

By disaggregating the vertically integrated network device stack, and reimagining the control plane as a device-independent operating system, several longstanding goals can now be achieved:

- Interoperability of different physical and virtual device types from different vendors.
- Optimization of device selection–for price and performance independently of services features.
- Continuous visibility of flows from source to destination.
- Common management framework for all devices.
- Programmability to shape network behavior according to users' needs.
- Automation of and by policy.

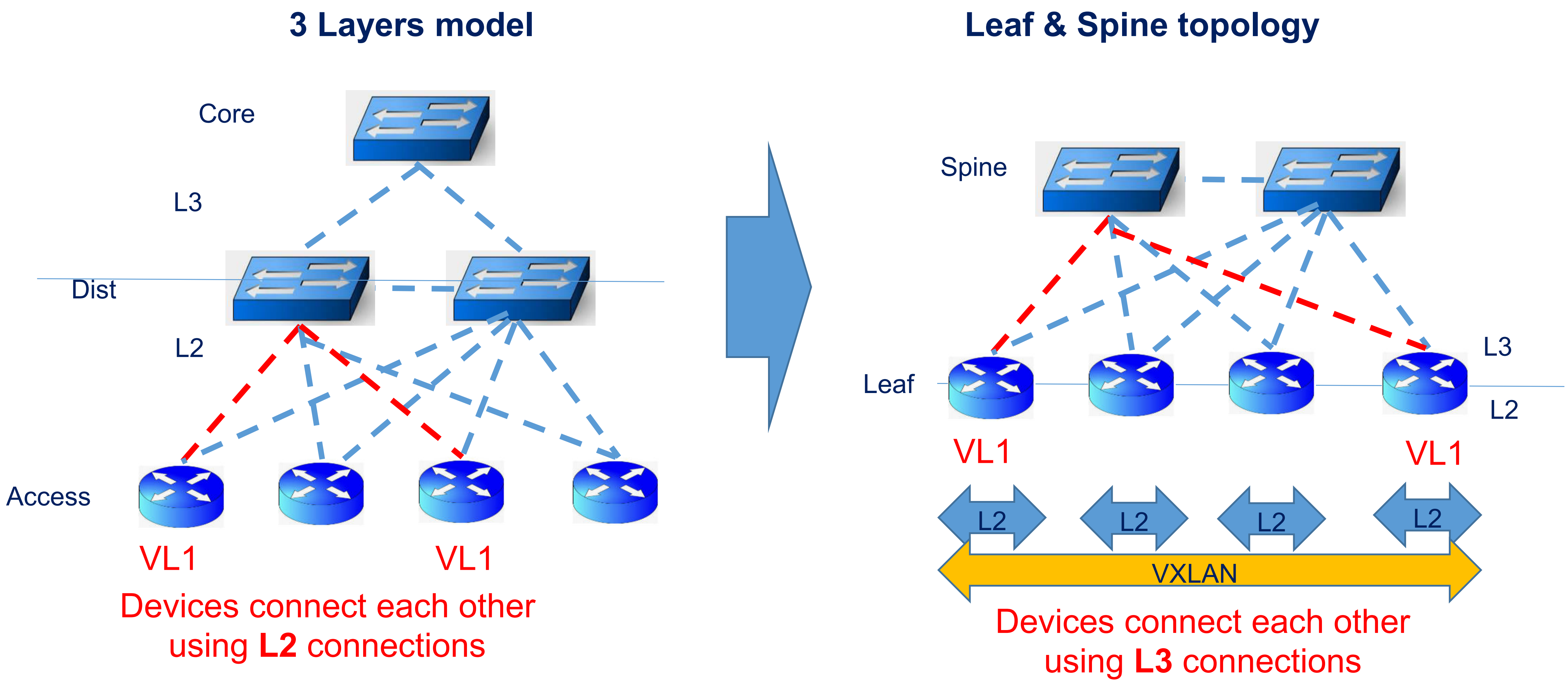
SDN CONTROLLERS

source: opendaylight.org

Network functions virtualization (NFV) brought the concept of compute virtualization to networking. The two have become closely intertwined, as SDN drives on-demand deployment of virtual network services when and where they are needed.
The drive for network programmability naturally led to an embrace of open source networking initiatives at every layer of the networking stack. OpenDaylight is the by far the largest and most mature project in this new stack, and a core component of the open source networking ecosystem.

Opendaylight is one of most used Controllers
Opendaylight is supported by Linux foundation
Opendaylight is free but requires knowledge to be used

SDN-FROM TRADITIONAL ARQ TO LEAF &SPINE



Leaf &Sine can be layer 2 or layer 3
Leaf & Spine layer 2, TRILL or SPB instead of STP
Leaf & Spine layer 3, VXLAN

SPB: Shortest path Bridging

SDN. LOGICAL ARCHITECTURE OF SDN

Original idea was to have switches controller-less, which should be controlled by external controllers throught Openflow

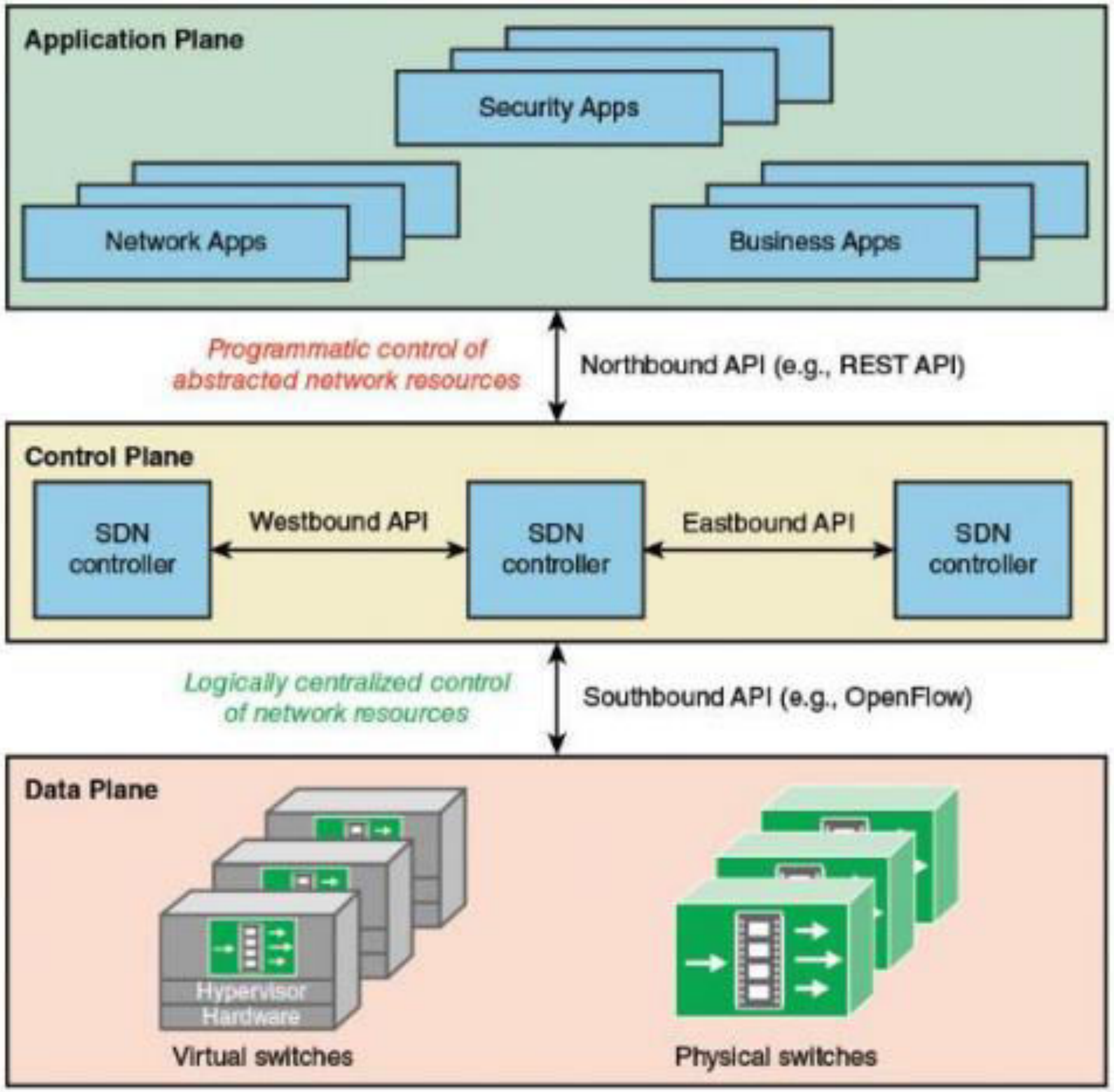
Typically in a network we will have a SDN controller for optical networks, another for IP networks and possibly another for Data Center.

However Openflow has not been adopted massively. Instead, other protocols as Netconf has been adopted

In Telco industry, SDN is used for automation reasons, to apply massively rules, configurations, traffic engineering, to download system image, however routers still have their own routing protocols

A switch depends on a SDN controller only to define routes internally within a server

Discuss the example of a vRAN

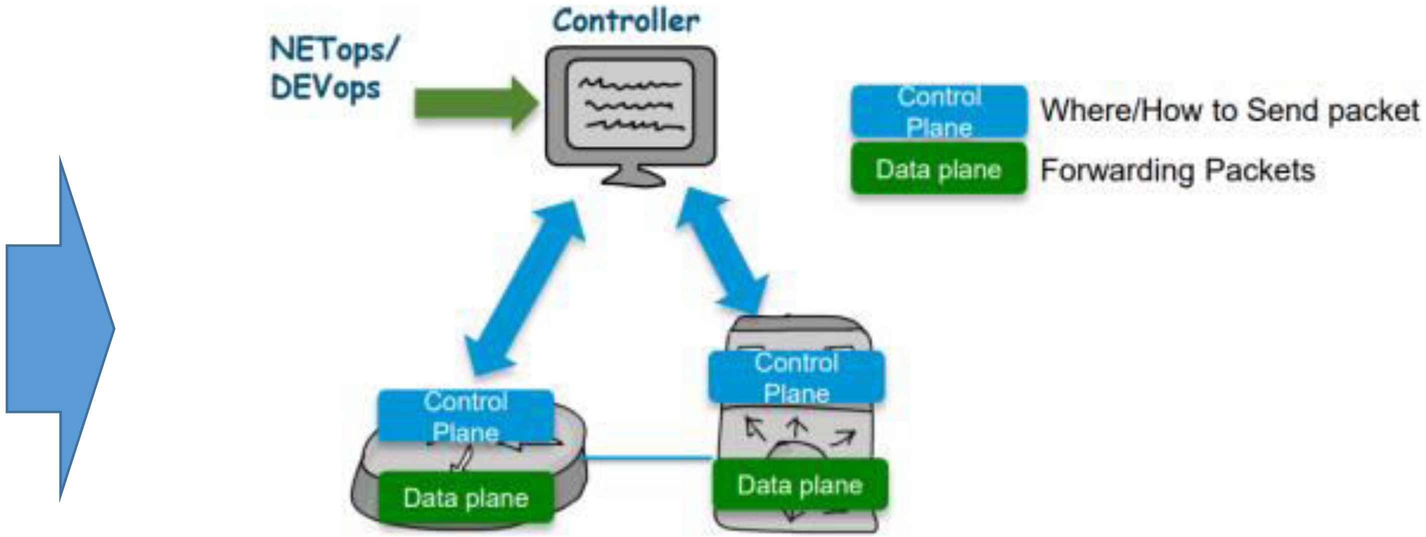


SDN. LOGICAL ARCHITECTURE OF SDN

The promise of SDN is to enable the following key features:

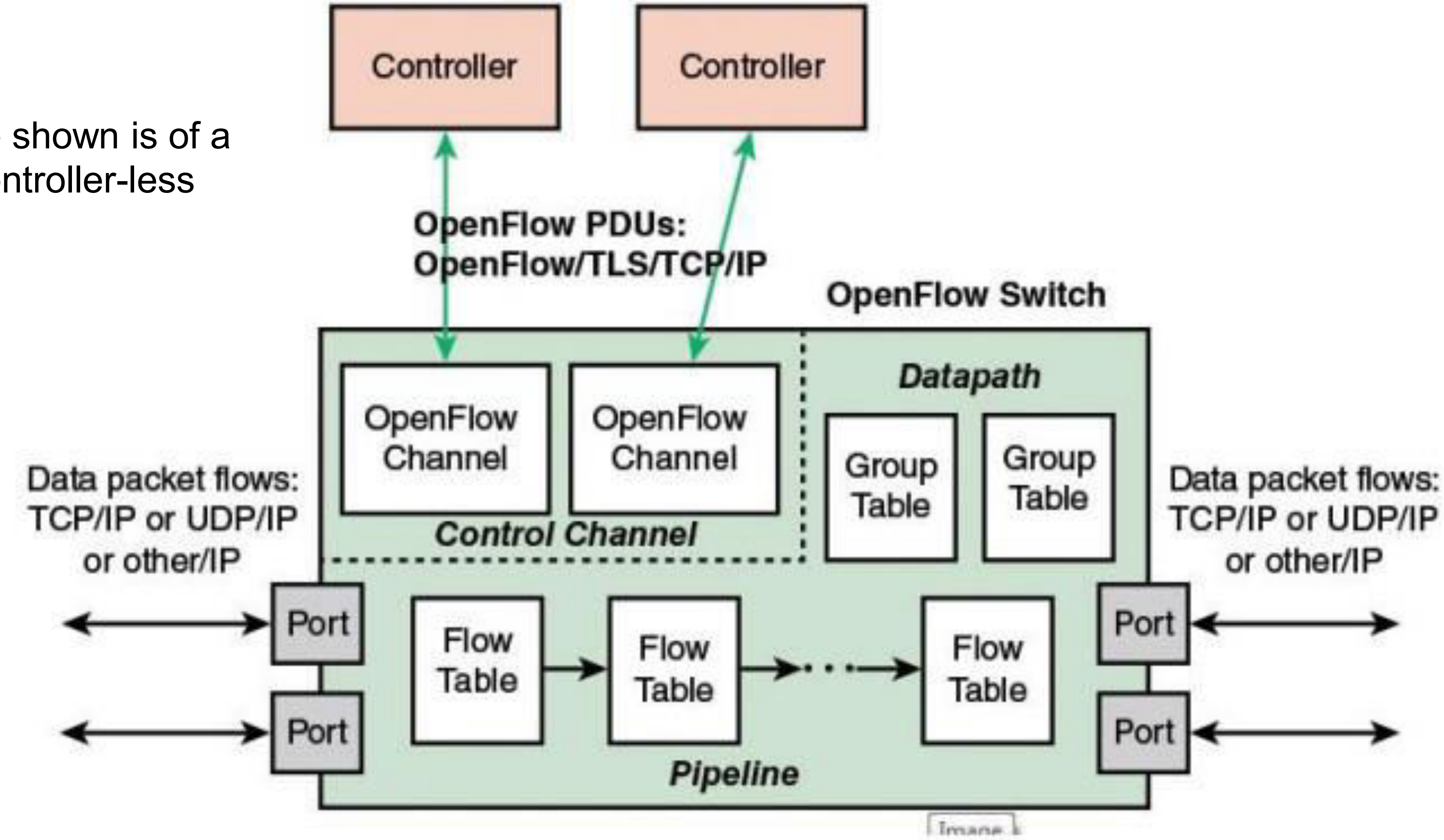
- Programmatic approach to dynamically create/deploy virtual networks
- Virtual network topology decoupled from the real physical network topology
- Coexistence of multiple virtual networks based on a shared physical network
- Isolation support that guarantees the independent operation of the virtual networks
- Improved utilization of physical network resources through pooling of network resources
- Reduced network design, complexities and reconfiguration time
- Flexible virtual network instantiation to meet diverse needs.

The classical approach (routers have their own control plane)

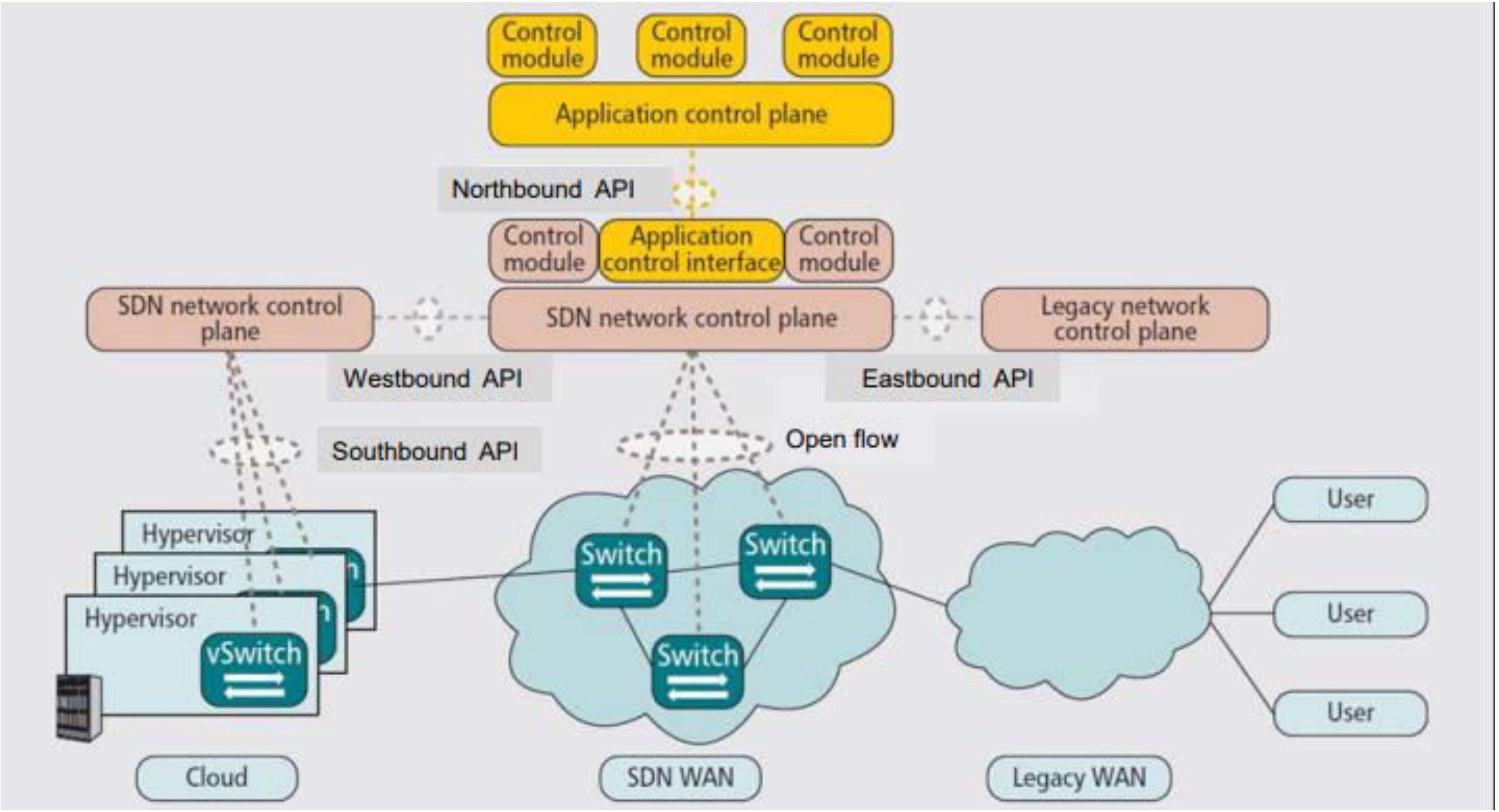


SDN. SWITCH OPENFLOW

The case shown is of a switch controller-less



SDN. SWITCH OPENFLOW

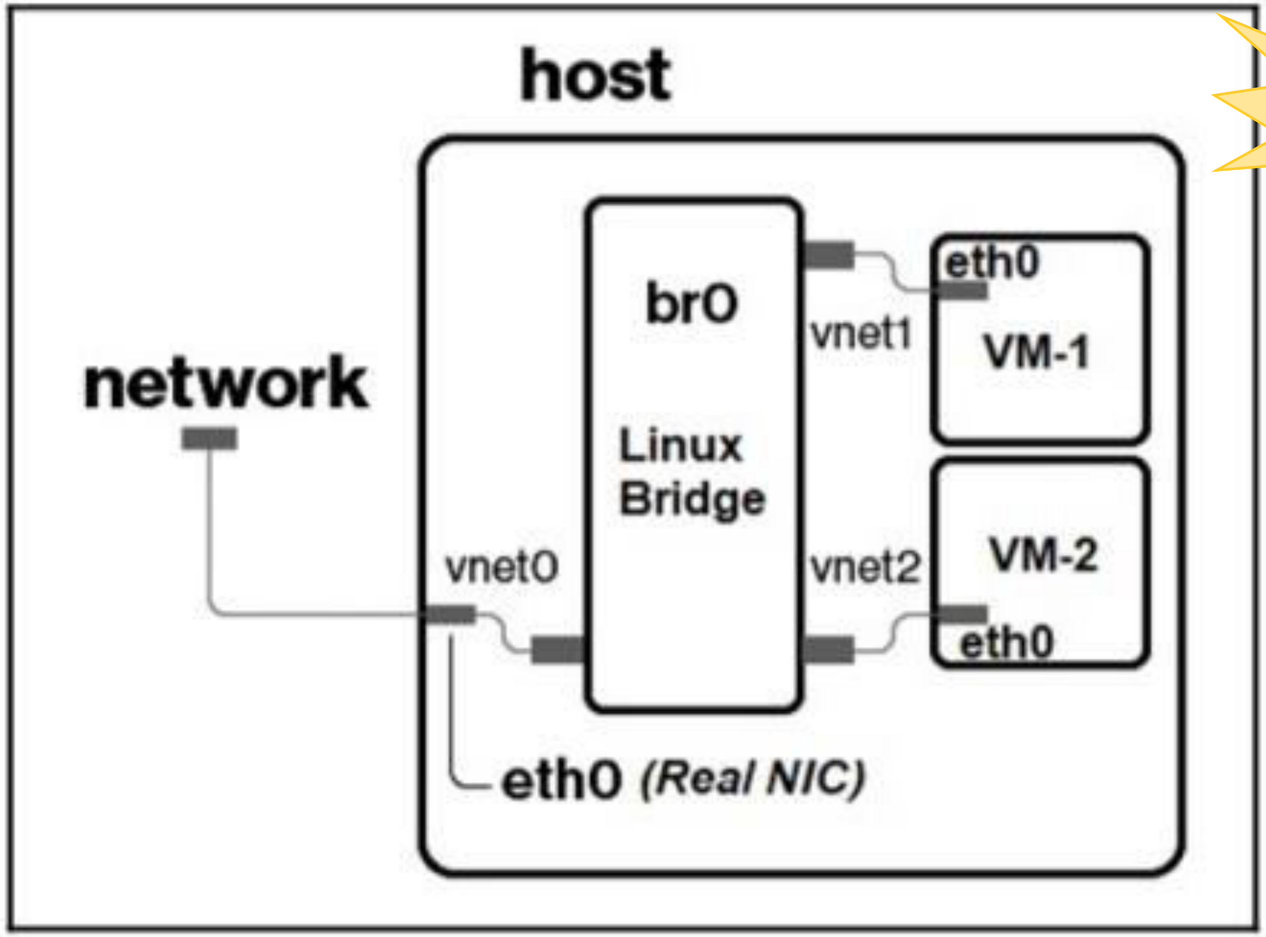


It applies both to physical and virtual switches

SDN. LINUX BRIDGE

Linux bridge is a software program that typically performs the layer-2 switch functionality. The Linux bridge is a virtual switch that allows one Virtual Machine (VM) to interconnect with another. This virtual switch cannot receive or transmit data packets on its own unless you bind one or more real devices to it:

When an instance (VM) is created, it comes with its vNIC. Each vNIC can be connected to another (if they belong to same network) across de Linux Bridge.
The Linux bridge
has some limitations however, so in some cases an OVS (Open Virtual Switch) must be used instead of the bridge



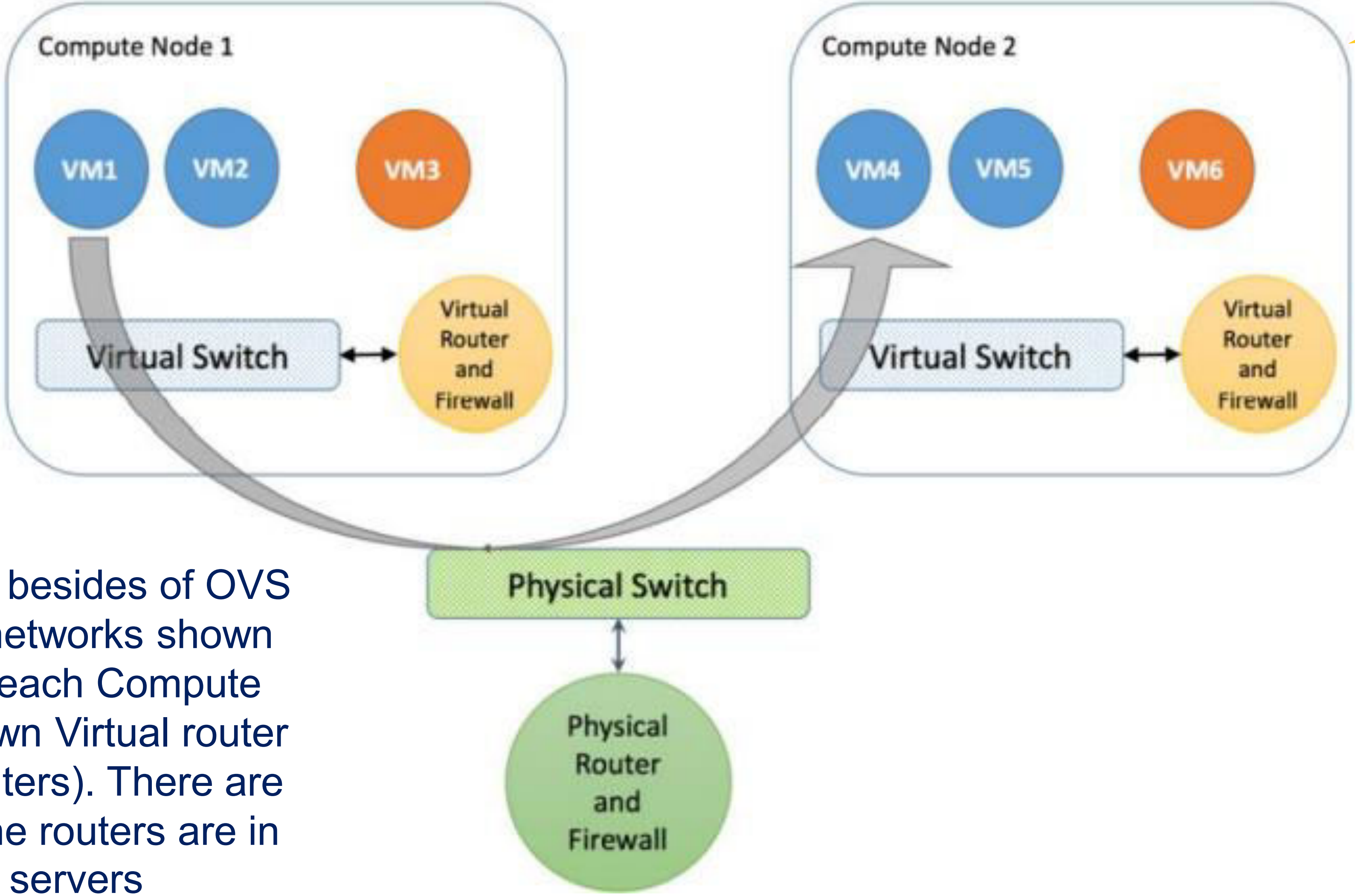
Review

We use OVS, routers etc,
To interconnect VMs.
But OVS, Routers, etc,
can also be VMs

SDN. VIRTUAL SWITCH

Interconnection of VM on different nodes

Review



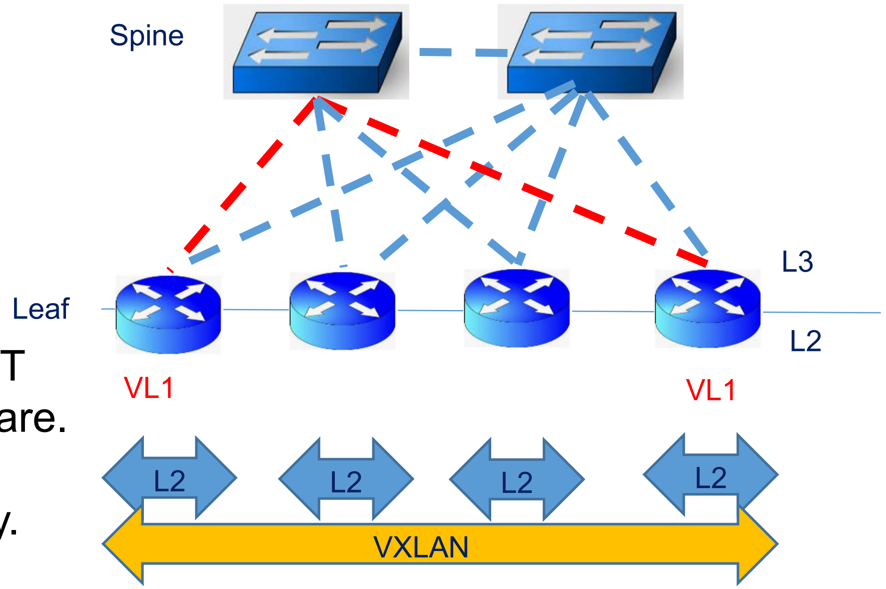
In this picture , besides of OVS (and different networks shown in dif colours), each Compute Node has its own Virtual router (distributed routers). There are cases where the routers are in other (specific) servers

SDN IN THE DATA CENTER

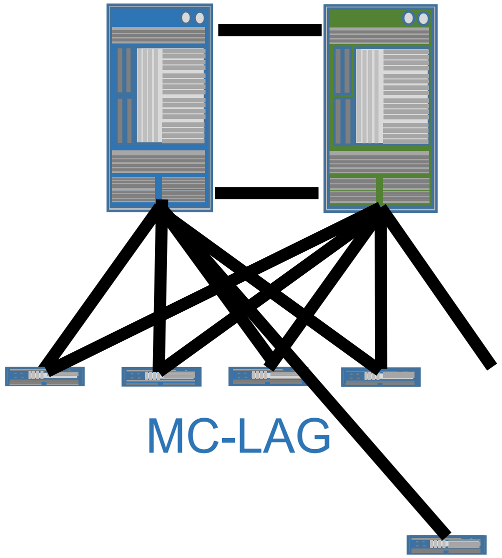
DATA CENTER ARQUITECTURE

-IP FABRIC (why?). What´s about layer 2?
-VXLAN. Layer 2 devices still exists
-EVPN-VXLAN

ENTERPRICE ARCHITECTURE EVOLUTION



- Leaf Spine architecture is not new, it was created by Charles Clos.
- Layer 2 equipment, layer 3 equipment, or multilayer are available. They are no longer just routers
- Early days Data Centers were Layer 2 based. The use of layer 2 even with SPT has decreased because when scaling, the problem of loops becomes a nightmare.
- Layer 3 is used instead in Leaf with Spine, with BGP for both under and overlay.
- Leaf spine is underlay SDN
- The leaf spine should be considered as a part outside of the virtual infrastructure.
- The SDN controller must impact both the logical and physical layers. Both overlay and underlay are part of SDN. A Plug-in is required for the SDN controller to configure the physical layer of any vendor. APSTRA is an SDN controller from Juniper which can automatically configure the physical equipment

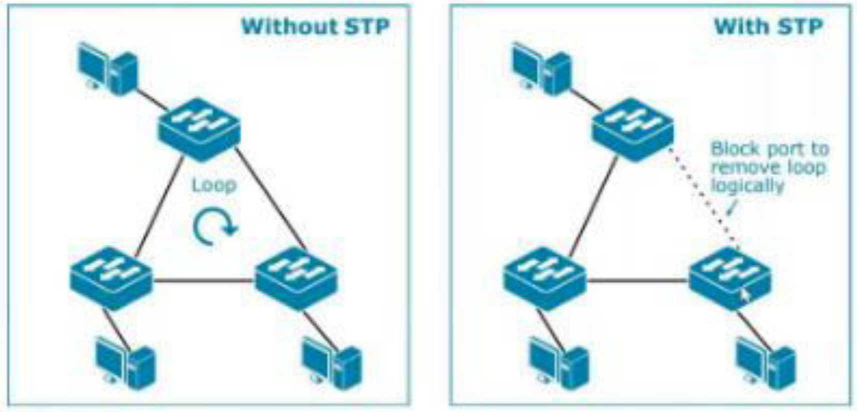


MC-LAG

Legacy Layer 2

- Limited Scale
- Complex Management
- Propietary
- Limited Resilience

STP review

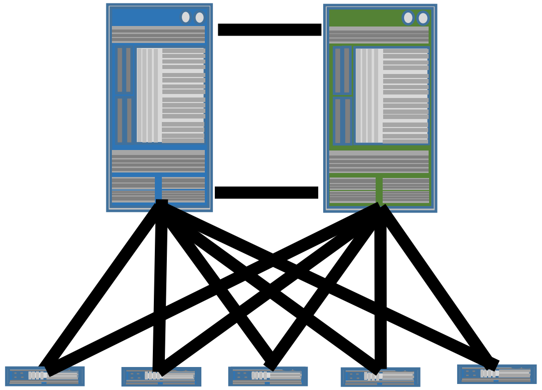


Spanning Tree Protocol (STP) is a Layer 2 network protocol used to prevent looping within a network topology. STP was created to avoid the problems that arise when computers exchange data on a local area network that contains redundant paths. If the flow of traffic is not carefully monitored and controlled, the data can be caught in a loop that circles around network segments, affecting performance and bringing traffic to a near halt.

Networks are often configured with redundant paths when connecting network segments. Although redundancy can help protect against disaster, it can also lead to bridgeor switch looping. Looping occurs when data travels from a source to a destination along redundant paths and the data begins to circle around the same paths, becoming amplified and resulting in a broadcast storm.

STP can help prevent bridge looping on LANs that include redundant links. Without STP, it would be difficult to implement that redundancy and still avoid network looping. STP monitors all network links, identifies redundant connections and disables the ports that can lead to looping.

ENTERPRICE ARCHITECTURE EVOLUTION - LEGACY LAYER 2



MC-LAG

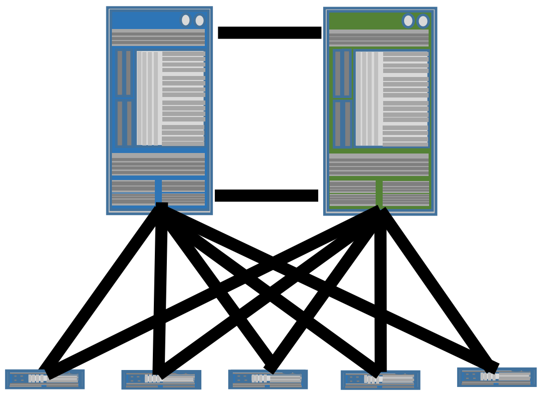
-The first generation of Data Center was made up of a multitude of Layer 2 equipment
-With MC-LAG or with Spanning Tree Protocol (Rapid STP; per VLAN STP) they solved both redundancy and load balancing between equipment
-Management is quite complex and not scalable
-There is a high probability of failure when configuring MC-LAG and STP.

Legacy Layer 2

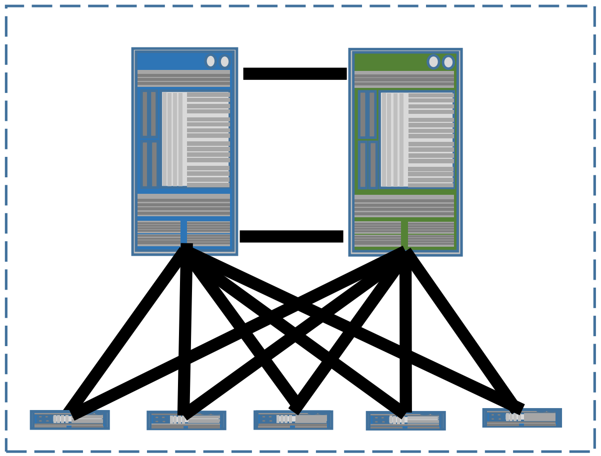
Limited Scale
Complex Management
Propietary
Limited Resilience

A **multi-chassis link aggregation group** (**MLAG** or **MC-LAG**) is a type of **link aggregation group** (LAG) with constituent ports that terminate on separate chassis, primarily for the purpose of providing redundancy in the event one of the chassis fails. Its implementation depends on each vendor and the protocol used between the chassis is **proprietary**.

ENTERPRICE ARCHITECTURE EVOLUTION - ETHERNET FABRIC



MC-LAG



Eth Fabric

Legacy Layer 2

Limited Scale
Complex Management
Propietary
Limited Resilience

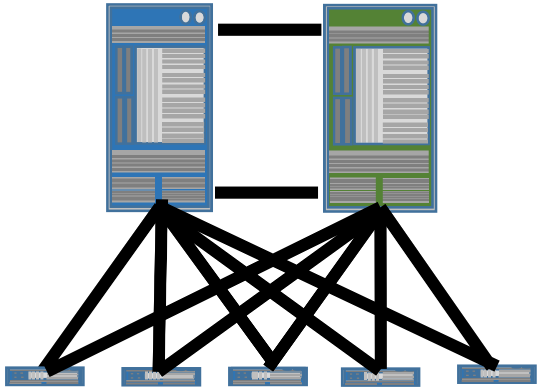
Ethernet fabric

Limited Scale
Simplified Management
Propietary
Limited Resilience

Ethernet Fabric

-Now all switches are integrated as only one great equipment with a great number of ports For Operator is a black box.
-The complexity of load balance and protection against failures are concealed
-Still proprietary technology
-Limited Scale (up to 24 to 36 equipments per Data Center).
Juniper calls it Virtual Chassis

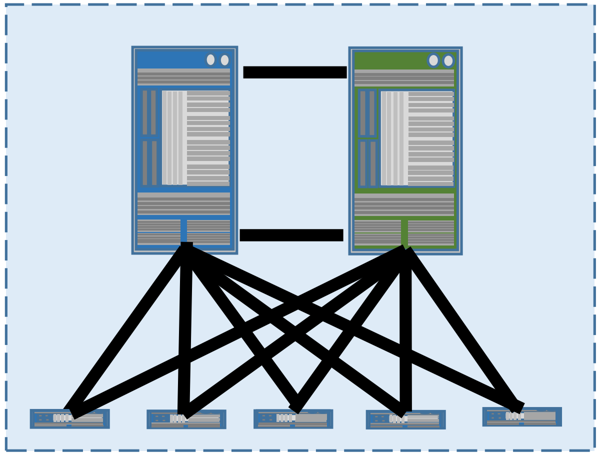
ENTERPRICE ARCHITECTURE EVOLUTION - IP FABRIC



MC-LAG

Legacy Layer 2

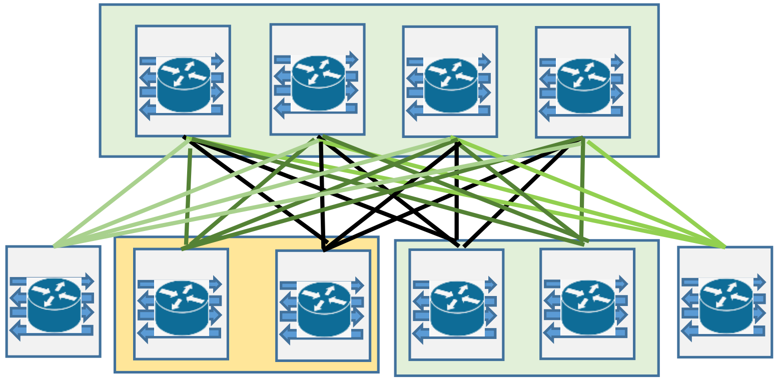
Limited Scale
Complex Management
Propietary
Limited Resilience



Eth Fabric

Ethernet Fabric

Limited Scale
Simplified Management
Propietary
Limited Resilience



Overlay

IP Fabric

Small-Large Scale
Simplified Management
Open Standards Management
Highly Resilient

ENTERPRICE ARCHITECTURE EVLUTION - IP FABRIC

-All nodes are resolved with IP switches-routers both at the LEAF and SPINE levels

-They allow to implement a routing protocol within this scheme based on the BGP protocol.

-Standards-based allowing mixing of equipment from different vendors

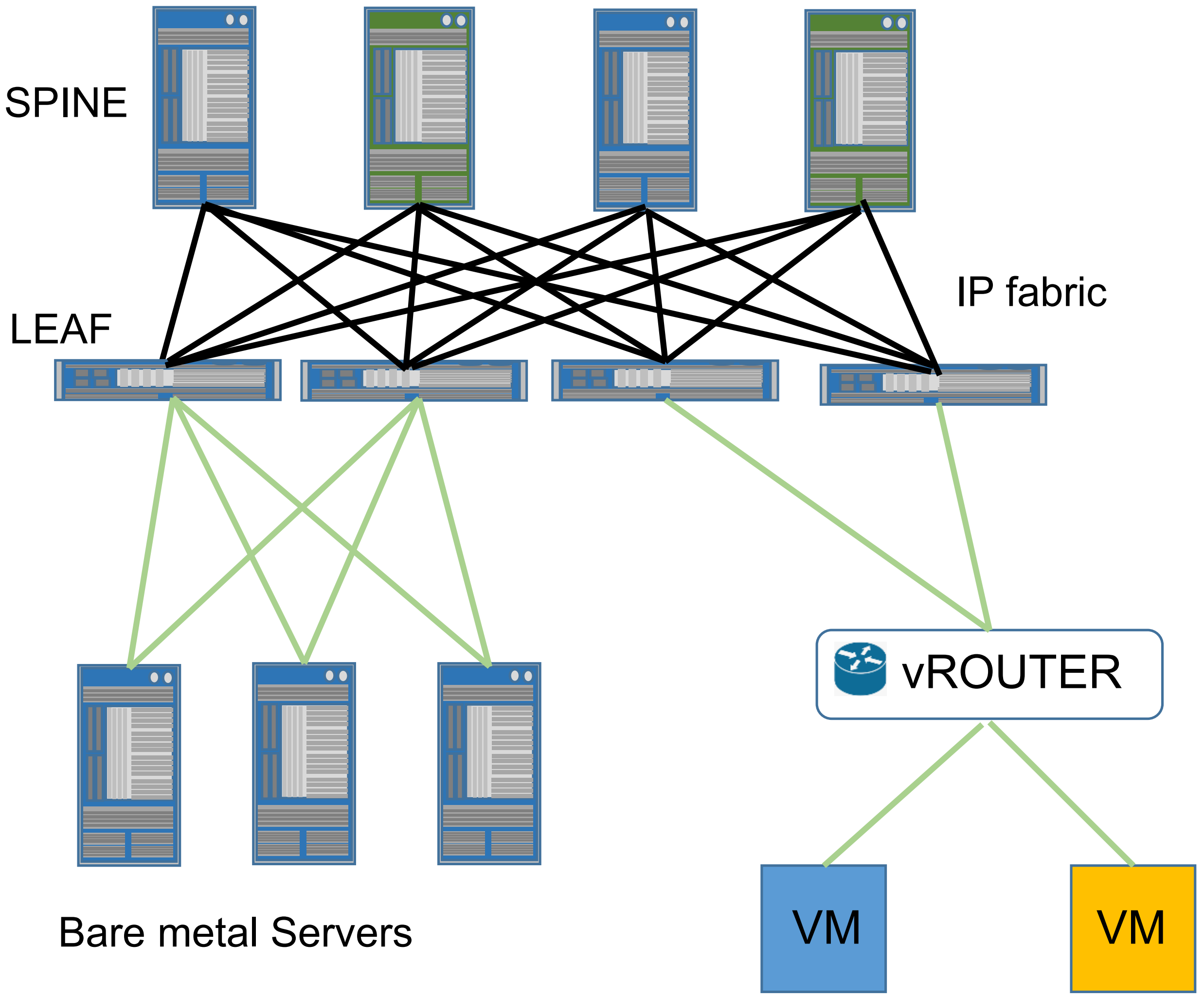
-Open standard

-At the IP level, it is possible to solve the demand for the service based on the reliability and robustness of protocols such as BGP and BFD.

-These protocols already work in the IP/MPLS backbone of the operators

-The idea is to bring them within the DC to have the same benefits of resilience and scalability

ENTERPRICE ARCHITECTURE EVOLUTION – WHY IP FABRIC?



Each equipment is IP

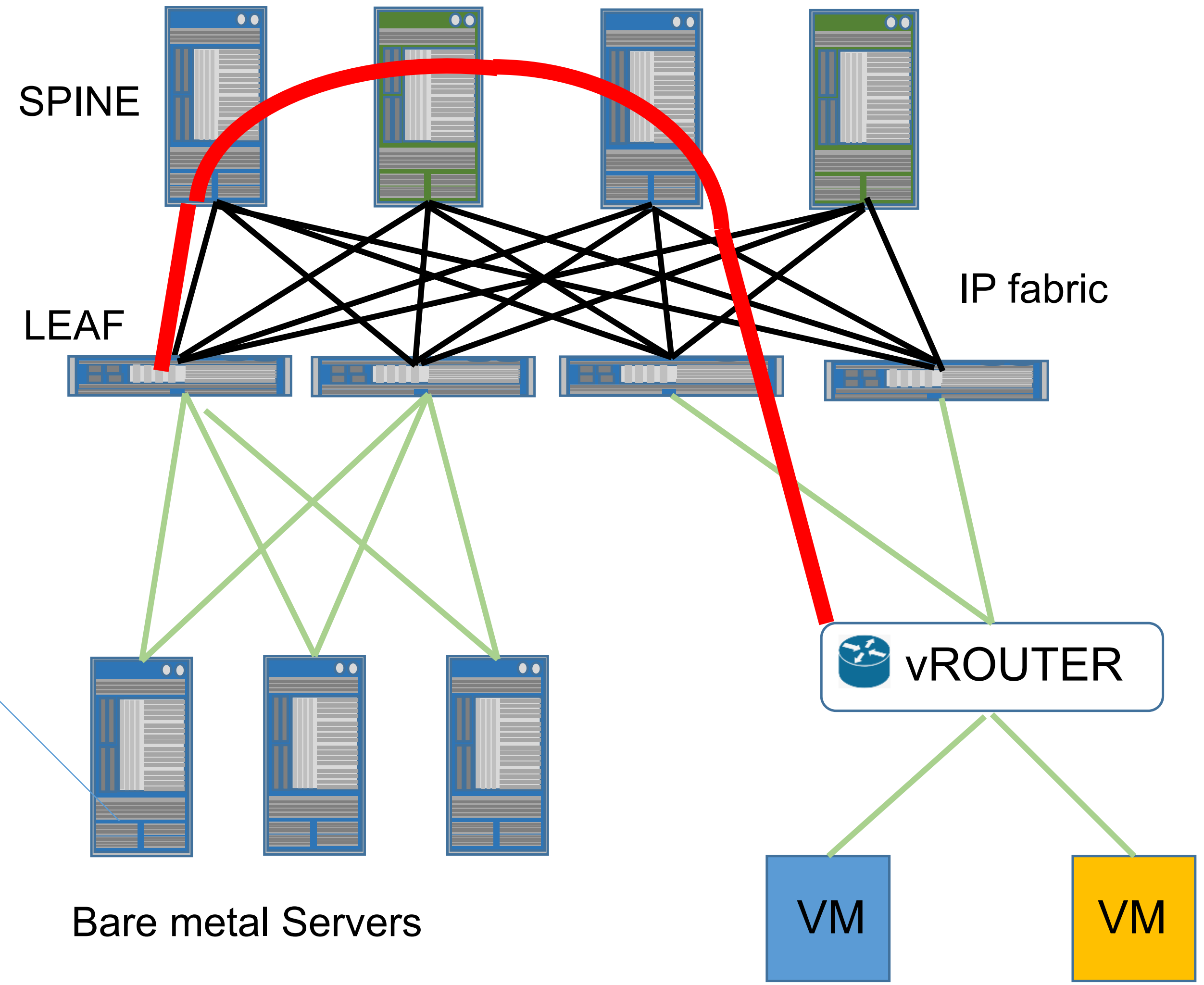
Allows scaling the number of nodes

It is resilient (Falt tolerant) like any IP backbone

The question is: How do I simulate a layer 2 connection (vlan) between 2 ports of 2 servers through the LEAFs, taking into account that now all the LEAF and SPINE devices are IP?

ENTERPRICE ARCHITECTURE EVOLUTION - IP FABRIC

VXLAN-EVPN



Why VXLAN?

- It provides connectivity for legacy applications that rely on L2 connectivity over IP fabric
- Provides a Bridge to connect heterogeneous workloads (baremetal, virtualized)

Why EVPN?

- Control plane for distributing MAC reachability. Reduces flood-and-learn in the network
- Based on BGP providing high Scalability
- Enables any workload Anywhere. Mobility withing and across DC

MAC reachability: BGP instead o ARP

EVPN - VXLAN

EVPN (Ethernet VPN) is a technology for carrying **layer 2 Ethernet** traffic as a virtual private network (VPN) using WAN (L3) protocols.
EVPN technologies include A) **Ethernet over MPLS** and B) **Ethernet over VXLAN**.

There are two types of layer 2 VPN: Point-to-point (Martini draft) and Point-to-multipoint.
Virtual Private LAN Service (**VPLS**) is a way of providing multipoint-to-multipoint Ethernet based communication over IP/MPLS networks. It allows geographically dispersed sites to share an Ethernet broadcast domain by connecting sites via pseudo-wires. **VPLS** is a Virtual Private LAN Service. **VPLS** is like making a Switch in the L3 network.

Originally *(case A)*), **VPLS**, an Eth-based VPN, had the forwarding plane on **MPLS**, and the control plane based on **BGP.**
Then , **EVPN** *(case B)*), an Eth-based VPN, which uses **VXLAN** for forwarding and **BGP** for control

VPLS	**MPLS / BGP**
EVPN	**VXLAN / BGP**

Each LEAF belongs to a different Autonomous System. In EBGP, since it is in the same Autonomous System, it does not have an autonomous system name. FRR (Free Range Routing is based on BGP (is called BGP unnumbered and include some modifications) . It uses the IP of the local-link of IPV6 (it is taken from each MAC Address).

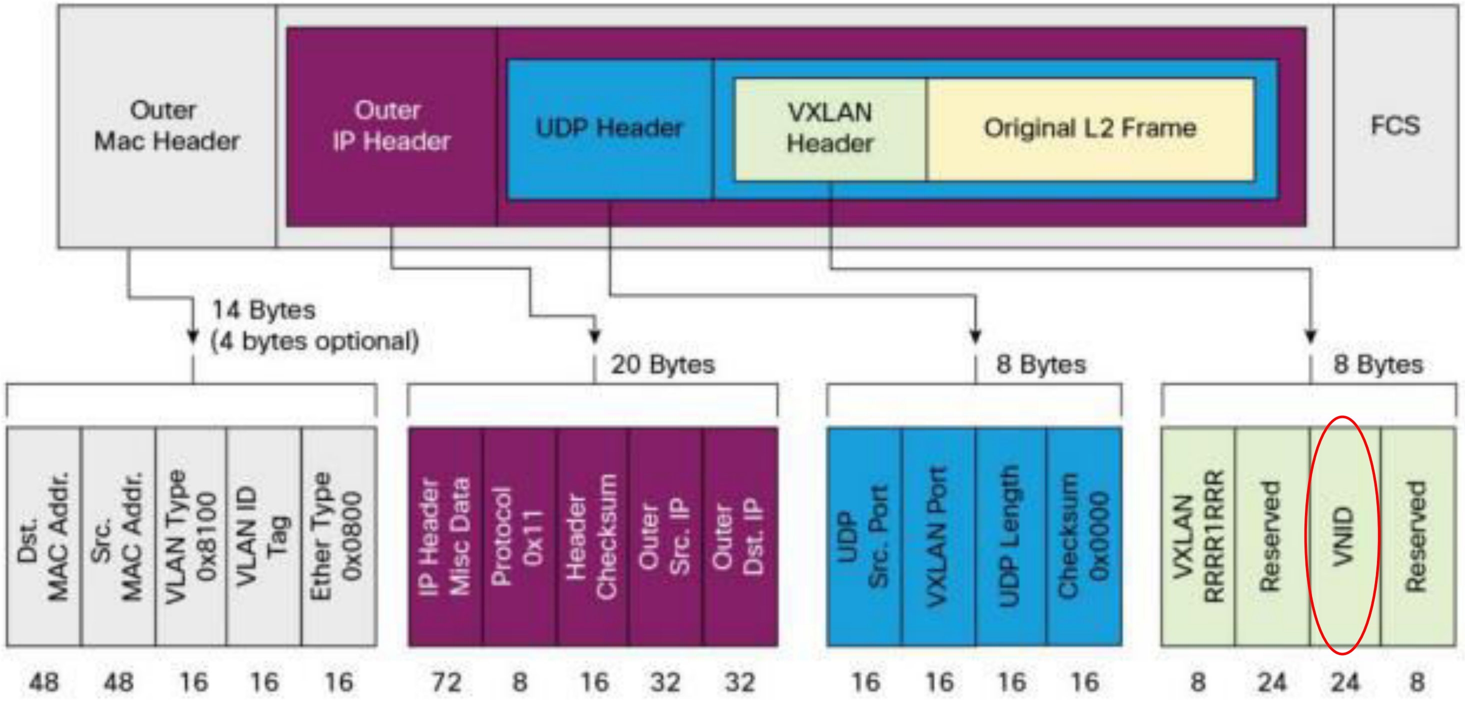
VXLAN (OVERLAY)

vXLAN tunnel that is built to transport the traffic is called OVERLAY, and it is done by the SDN Controller (while LEAF and SPINE switches are called UNDERLAY)

VXLAN

VXLAN defines a MAC-in-UDP encapsulation scheme in which the original Layer 2 frame is added a VXLAN header and then it is mapped to the payload of a UDP message. With this encapsulation MAC-in-UDP , VXLAN tunnels the Layer 2 network through the Layer 3 network. The VXLAN packet format is shown in the figure below.

Each VNID Correspond to one VLAN
The VTEP maps VNID with VLAN



As shown in the figure, VXLAN introduces an 8-byte header consisting of a VNID of 24 bits and some reserved bits. The VXLAN header along with the original Ethernet frame goes in the UDP payload. The 24-bit VNID is used to identify Layer 2 segments and to maintain Layer 2 isolation between segments. With all 24 bits in the VNID, VXLAN can support 16 million LAN segments.

VXLAN CONTROL PLANE

- VXLAN Control Plane
  - Multicast signaled VXLAN
    - MAC learning through multicast
    - Resource intensive
    - Slow convergence and updates
    - Not agile (requires some manual configuration/VNI mapping)
  - EVPN signaled VXLAN
    - MAC learning through BGP signaling
    - Scalable
    - Fast convergence and updates
    - Automated Virtual Tunnel Endpont (VTEP)/VNI discovery through BGP

Chosen standard for control plane in VXLAN is EVPN

RIC

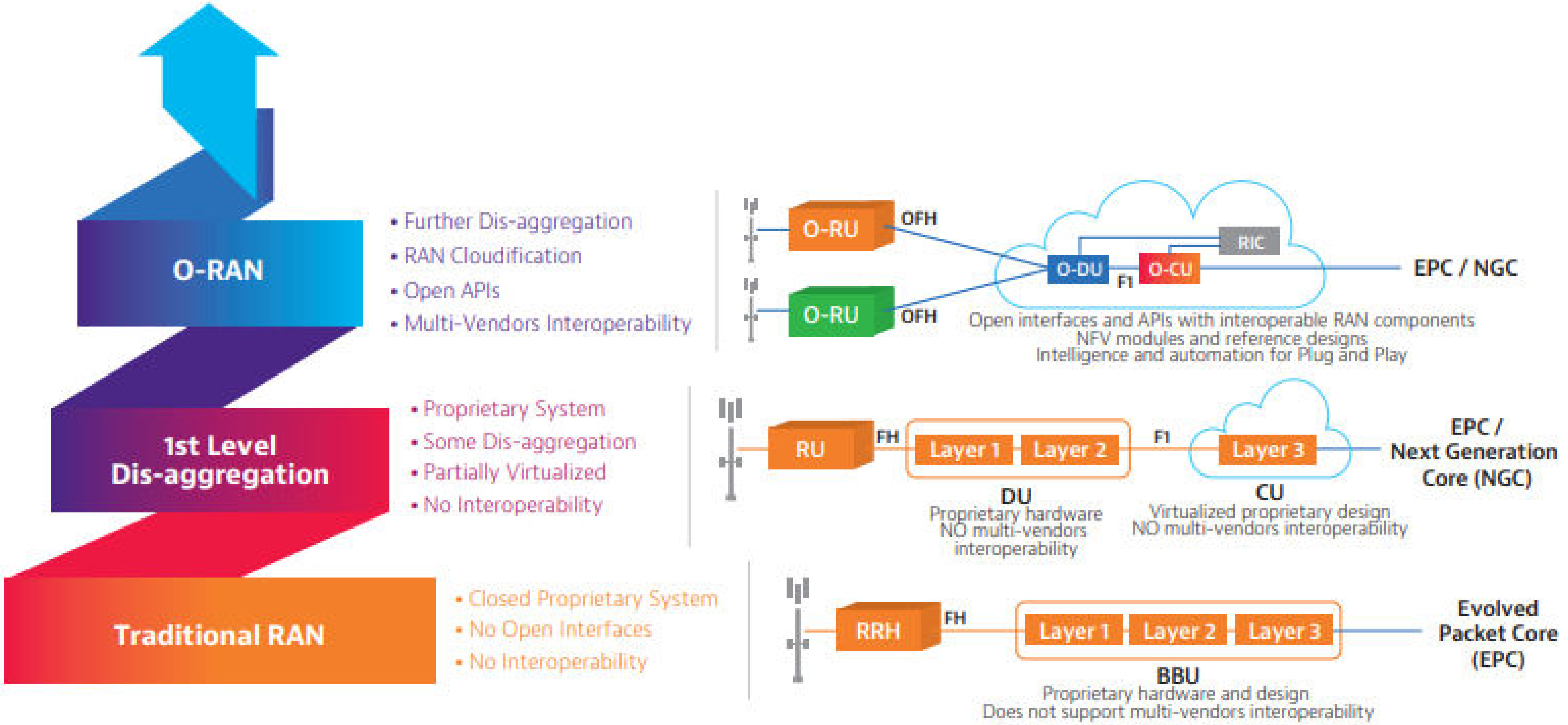
RIC (RAN Intelligent Controller)

- Automatización
- Optimización
- Información de parámetros de red
- Apertura de la RAN y exposición de parámetros
- Interfaces abiertas
- Acción en tiempo real
- Acciones predictivas
- AI / ML

RIC:RAN Intelligent Controller)
  Near-RT-RIC
  Non Real Time-RIC

O-RAN-WG3.E2GAP, “O-RAN Working Group 3, Near-Real-time RAN Intelligent Controller, E2 28 General Aspects and Principles”. 29
O-RAN-WG3.E2AP, “O-RAN Working Group 3, Near-Real-time RAN Intelligent Controller, E2 30 Application Protocol (E2AP)”. 31
O-RAN-WG1.OAM Architecture, “O-RAN Operations and Maintenance Architecture”.

INTRODUCCIÓN A O-RAN. EVOLUCIÓN DE LA RAN



RIC- Radio Access Transport Network

Antenna
RRU
BBU 5216 / 5212/ 3900 /etc — BBU

eNB/gNB — MME/AMF

CU
Centralized Unit

- CU support for Higher layer Protocol stack,
- Single CU for each gNB.
- CU can connect to multiple DU

(L3) RRC
(L2) PDCP SDAP

DU
Distributed Unit

- Lower Layer of the gNB protocol stacks
- Multiple DU can be connected to one CU

(L2)RLC
(L2)MAC

RU
Radio Unit

- Centralized processing,Higher Layer elements of the gNB protocol stack(one CU to Multiple Dus)

PHY

CAFETELE TELECOM TRAINING

RAN Evolution from traditional to current version

MAC: hard porpuse (trasport block, Log Ch ID, random Access, CA)
RLC: transp mode, ack mode

Digita Radio
Fronthaul connectivity
PHY
RF Interface

Radio Unit | Radio Unit

Fronthaul

DU runs the Lower layer
Protocol stack like RLC, MAC and part of PHY layers
Multiple DU connect to each CU

5216
5212
3900

Baseband | CU

Midhaul

DU

L2+l3+control, Higher layer Processing
A CU with mutiple DU support multiple gNBs

Backhaul

Core Network | Core Network

TRADICIONAL

En 5G pasamos de 32 a 64 LCID

OPEN RAN

RIC- Mapping RAN to Transport Network

Service Layer

E2E services (Network slice) ⟷

Mobile Network

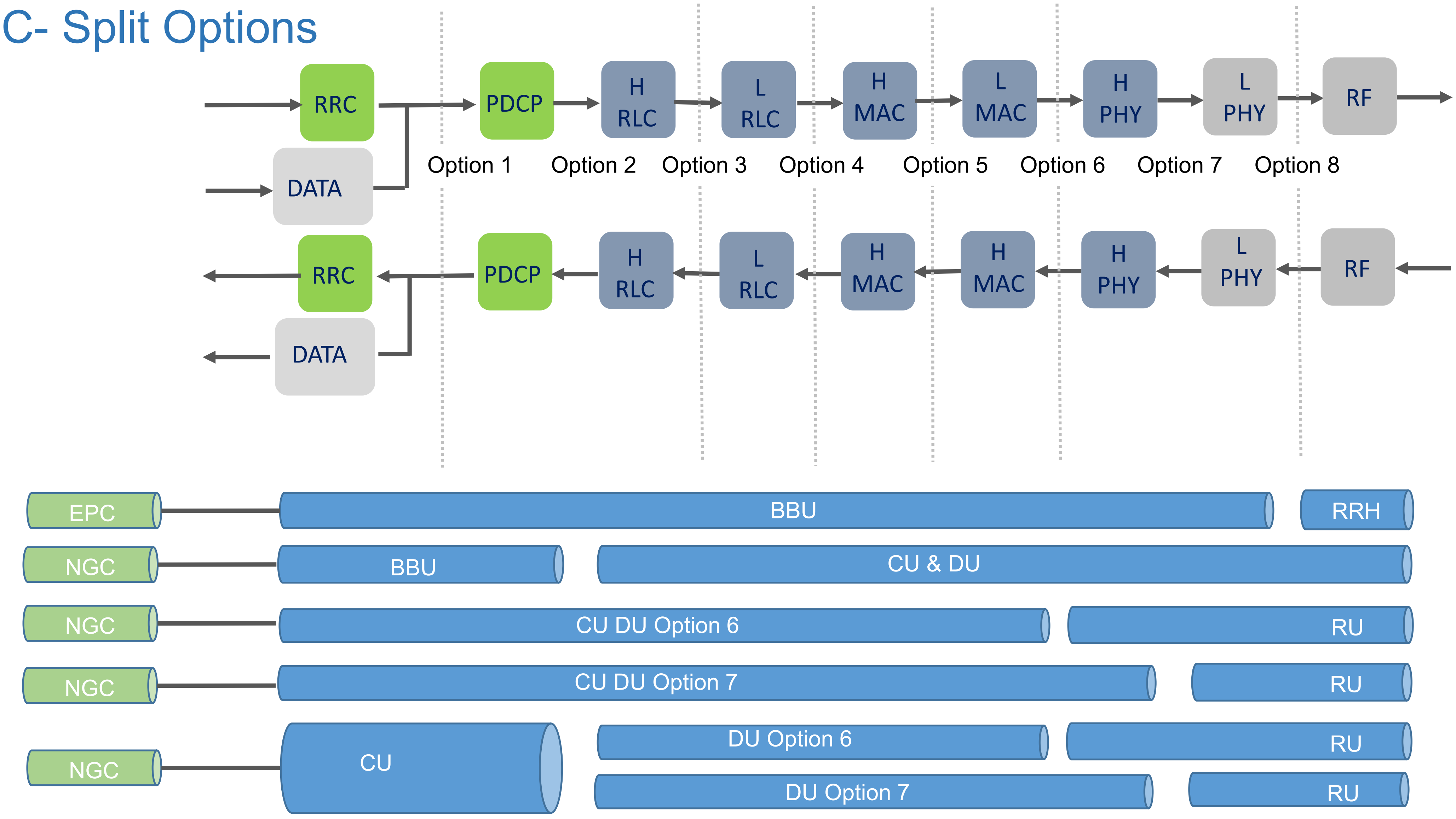
RU — LLS — DU — HLS — CU — 5GC

Fixed Transport Network

FRONTHAUL	MIDHAUL	BACKHAUL
0 -10 Km	10 -4 Km	40 - 200 Km
50- 200 uS	1-2 mS	< 10 mS
100 G+ link	100 G+ link	400 G+ link
P2P & Point to Multipoint	L2/L2 Connectivity	L2/L2 Connectivity
	Point to Multipoint	Point to Multipoint

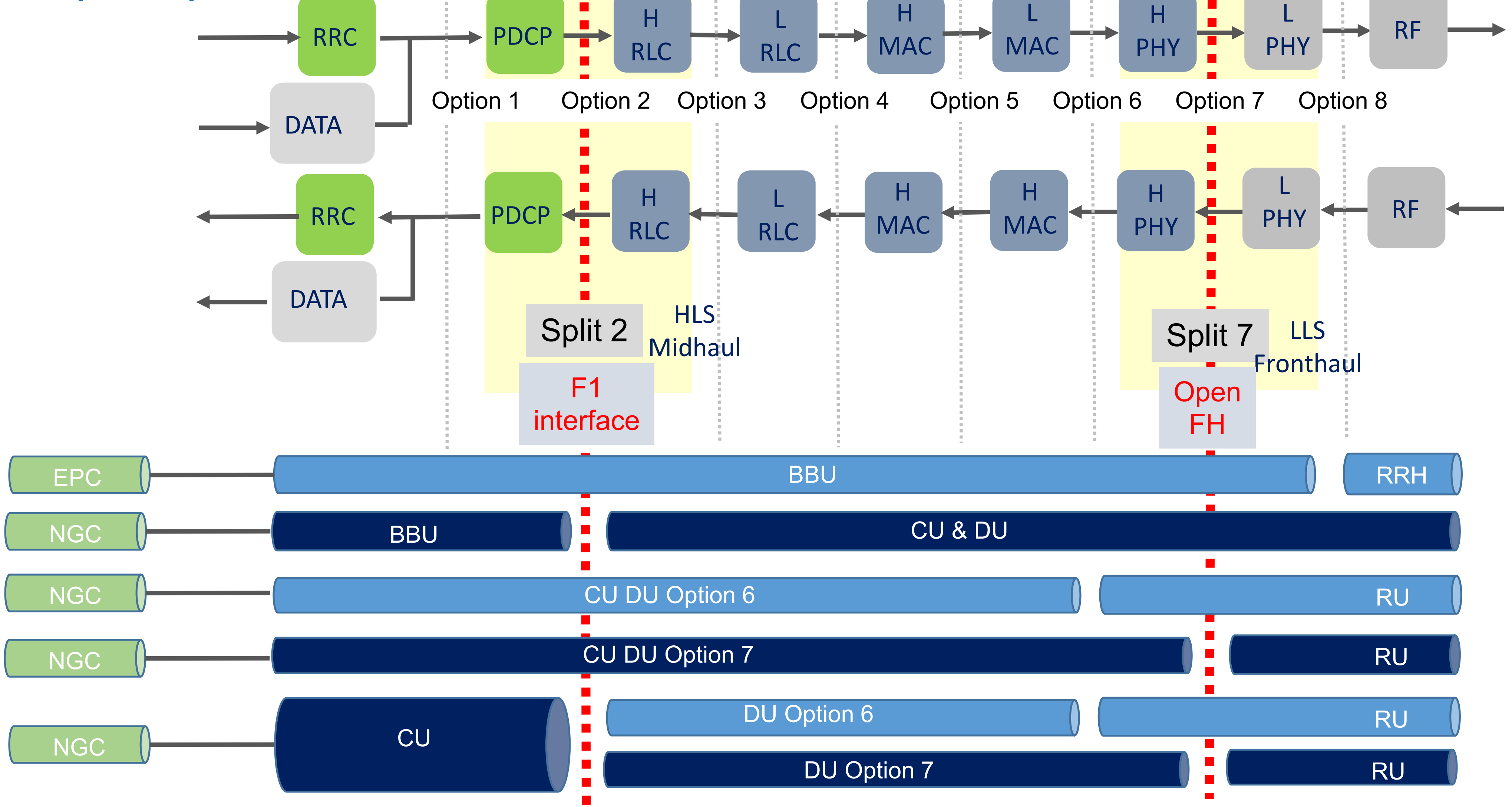
Diapo sobre los slices

RIC- Split Options



RAN Split Options(source: NGNM 2018)

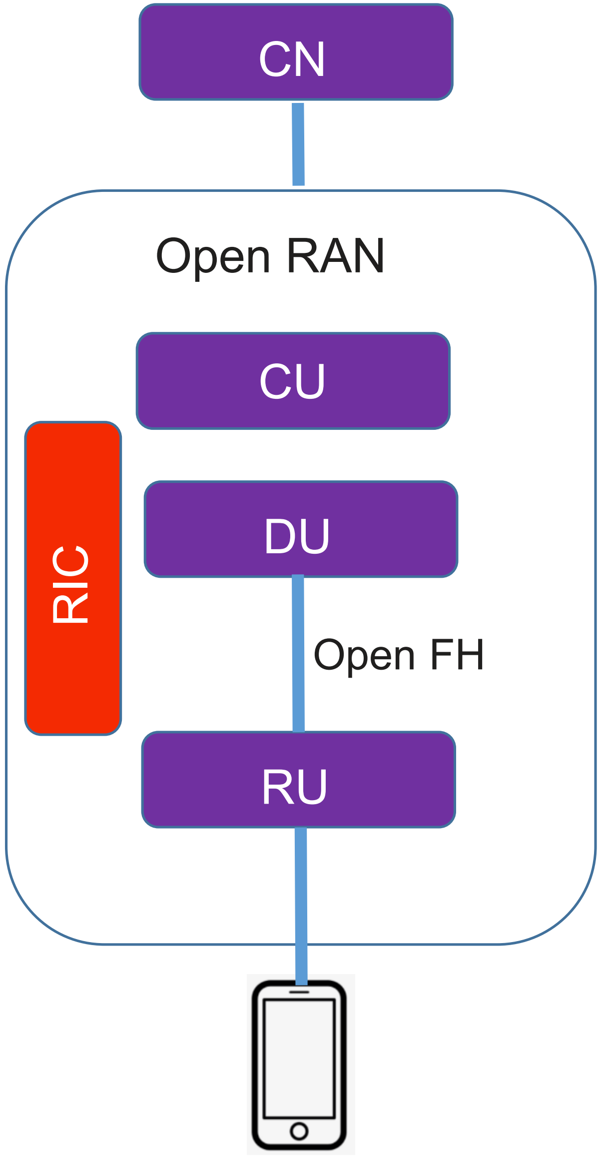
RIC Split Options



RAN Split Options(source: NGNM 2018)

RIC

En las redes tradicionales, los algoritmos de optimización son cerrados.
En O-RAN se hace una abstracción y existe una apertura que permite implementar funciones por fuera, como es el caso de RIC



Near-Real Time RIC, PROPÓSITO GENERAL

La arquitectura de Near RT RIC y sus interfaces internas deben ser abiertas y soportar xApps de terceros.
El Near RT RIC consiste de diversos xApps (pueden ser microservicios) y un conjunto de funciones de plataforma que suelen usarse para dar soporte a las funciones específicas hospedadas por las xApps

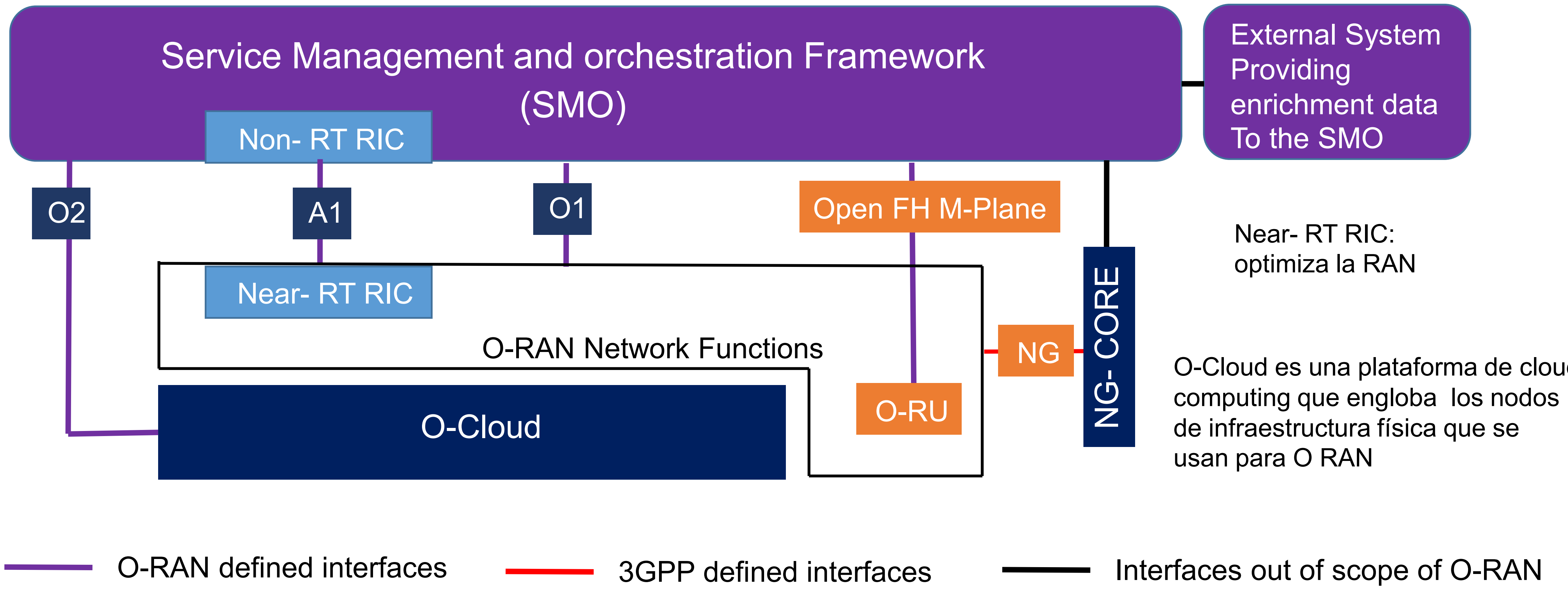
Near-RT RIC proporciona una base de datos con información de la RAN (cuasi tiempo real), información histórica, configuraciones.

xApps son simplemente aplicaciones que corren en el Near-RT RIC constituidas por uno o mas microservicios. En el onboarding se identifica que datos consumen y qué datos proveen (rol de consumer y de producer).
Las xApps son independientes del Near-RT RIC, son provistas por terceros

Arquitectura Near-RT RIC
1-xApps
2-Seguridad
3-Infrastructura de mensajería
4-Gestión de la suscripción
5-Servicios de Gestión
6-Mitigación de conflictos

¿Qué implicancias tiene el hecho de ser provistas por terceros?

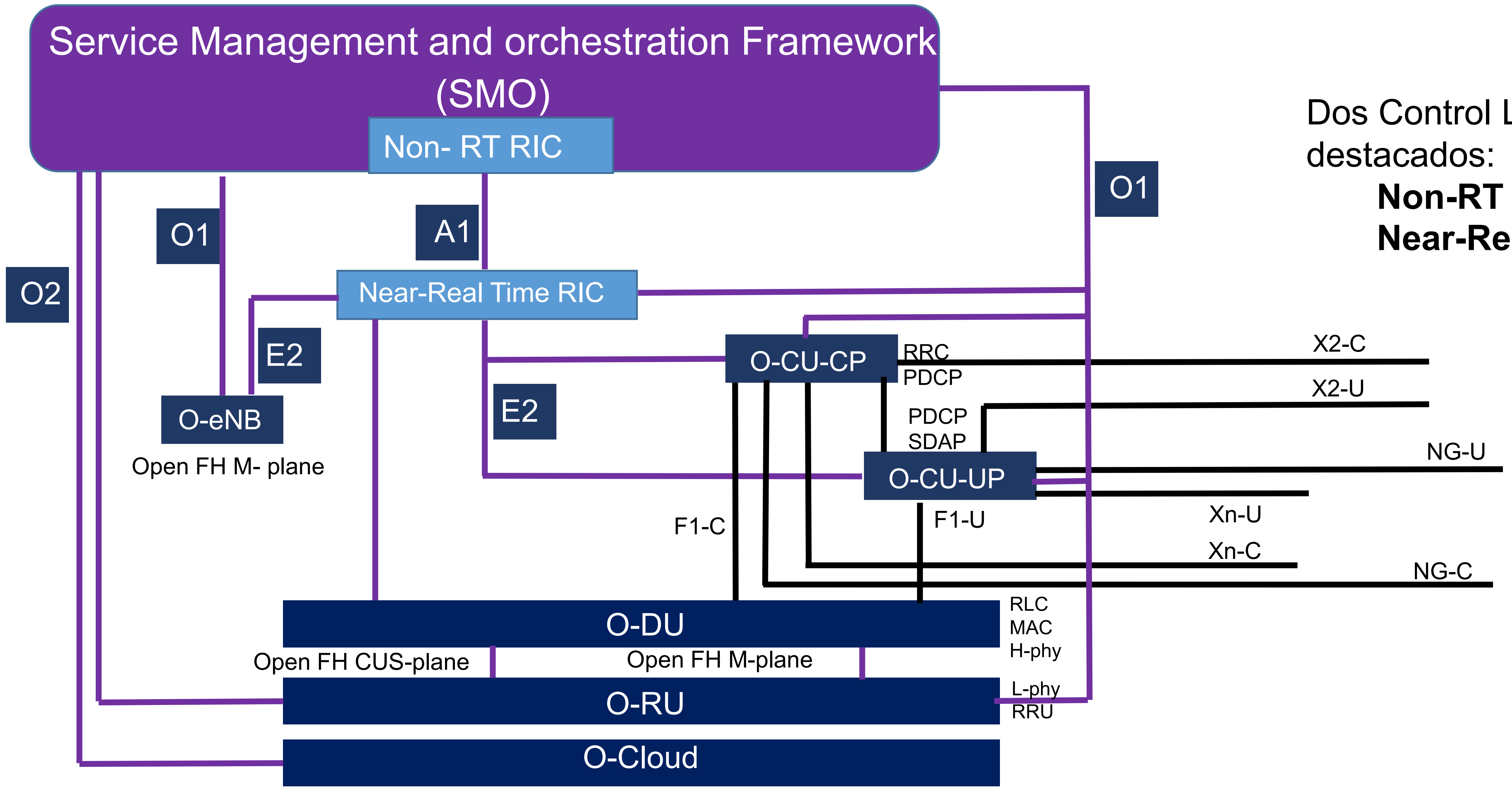
RIC, High Level Architecture



Near- RT RIC: optimiza la RAN

O-Cloud es una plataforma de cloud computing que engloba los nodos de infraestructura física que se usan para O RAN

RIC- Logical Architecture



Dos Control Loops destacados:

Non-RT RIC

Near-Real Time RIC

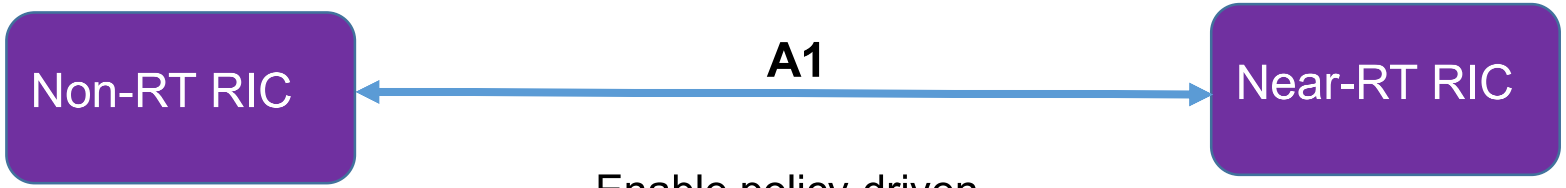
RIC What is RIC

RAN INTELLIGENCE CONTROLLER

Non-RT RIC

Near-Real Time RIC

Support intelligence RAN Optimization (policy-based Guidance)
Support AI/ML workflow.
KPI checking like today



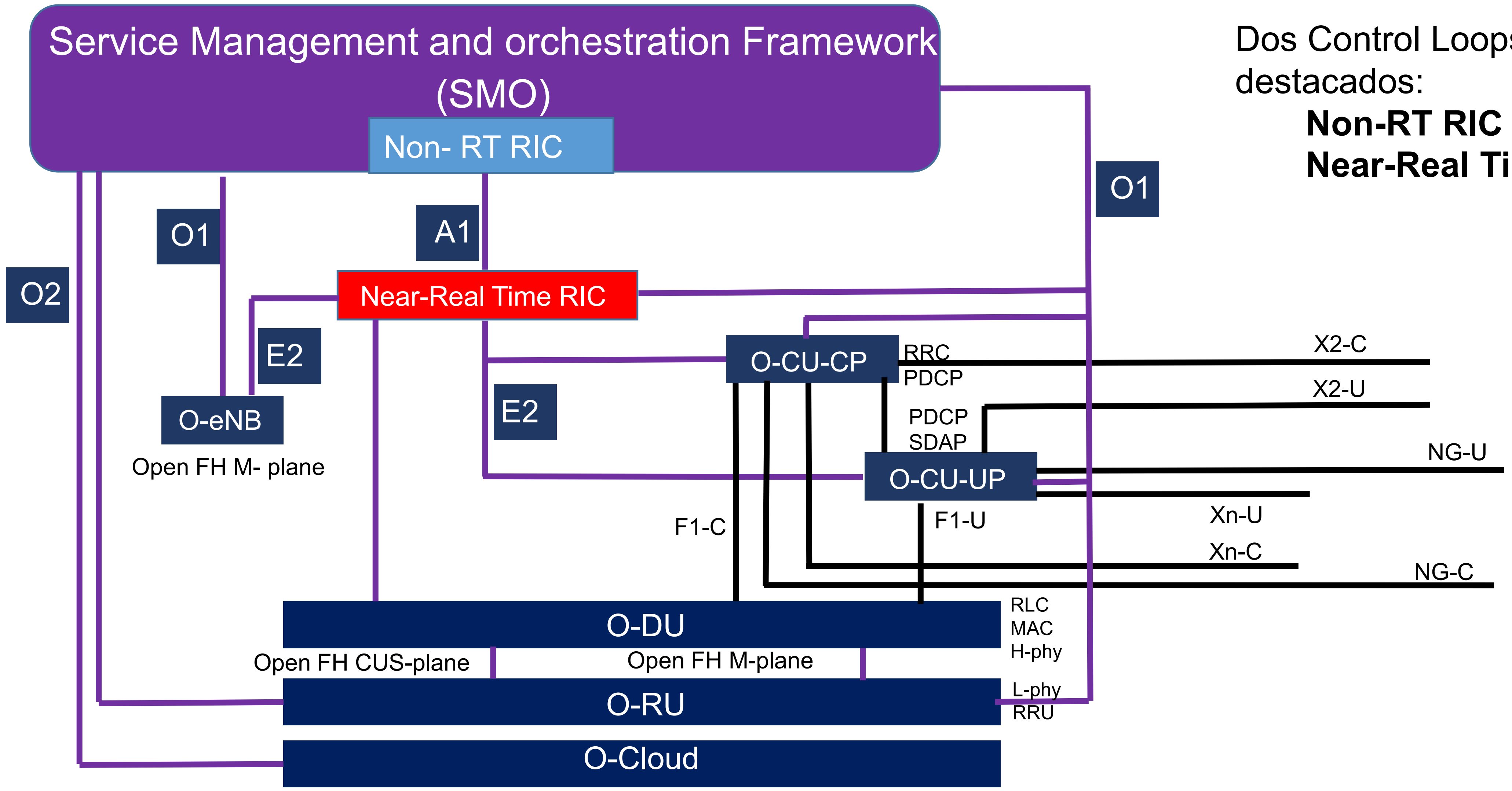
Enable policy-driven Guidance of Near-RT RIC Applications and functions, and support AI/ML workflow

ML model management
Kpis: accesibilidad retenibilidad
Throughput
AI based
Data analytics
AI learning Machine training interface

Main functions
Near RT control
Optimization of the “e2” nodes function resources via data collection from Network

Two main functions
Non RT RIC Framework (internal to SMO)
Non RT RIC Applications (rApps) (modular apps that leverages the functionalities exposed by Non-RT RIC framework to perform RAN optimzation

RIC- Location of Near-RT Controller in O-RAN Architecture



Dos Control Loops destacados:

Non-RT RIC

Near-Real Time RIC

Interfaz E2

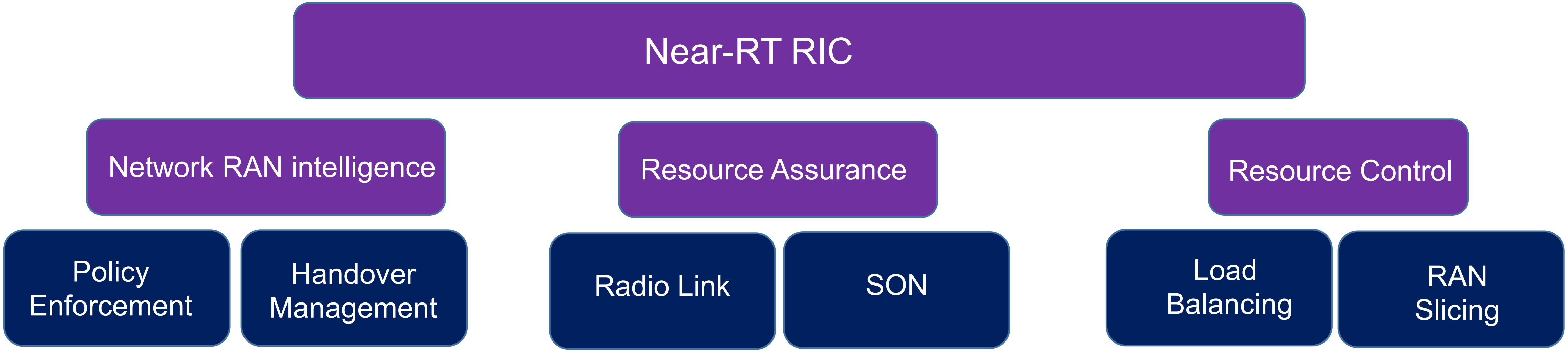
Entre:

NRT RIC O-CU

NRT RIC O-DU

Propósito de Near-RT RIC

Minitoreo de KPIs (drops, tilt, etc)
Near RT RIC proporciona datos relativos a la RAN, configuraciones, niveles a lo largo del tiempo.
Proporciona herramientas de ML que soportan Data Pipeline,
Messaging infrastructure security function que también ayuda a optimizar la red



Propósito de Near-Real Time RIC

KEY TOPIC

Near-RT RIC architecture and internal interfaces must be open to support 3rd party xApps.

Near-RT RIC consist of multiple xApps and a set of platform functions that are used to support the specific functions hosted by xAppspicitos

Near-RT RIC Architecture
- xApp
- Security
- Messaging infrastructure
- Suscription Management
- Management Services
- Conflict Mitigation

Mitigación de conflictos
- Potenciales superposiciones o req conflictivos desde las dif xApps
- Conflictos directos
- Conflictos indirectos (no observables directamente)
- Conflictos impicitos

Infrastructura de Mensajería
Interacción de mensajes dentro de propio N-T RIC
- baja latencia de mensajes
- Registración (de los endpoints)
- Discovery
- Delete

RIC

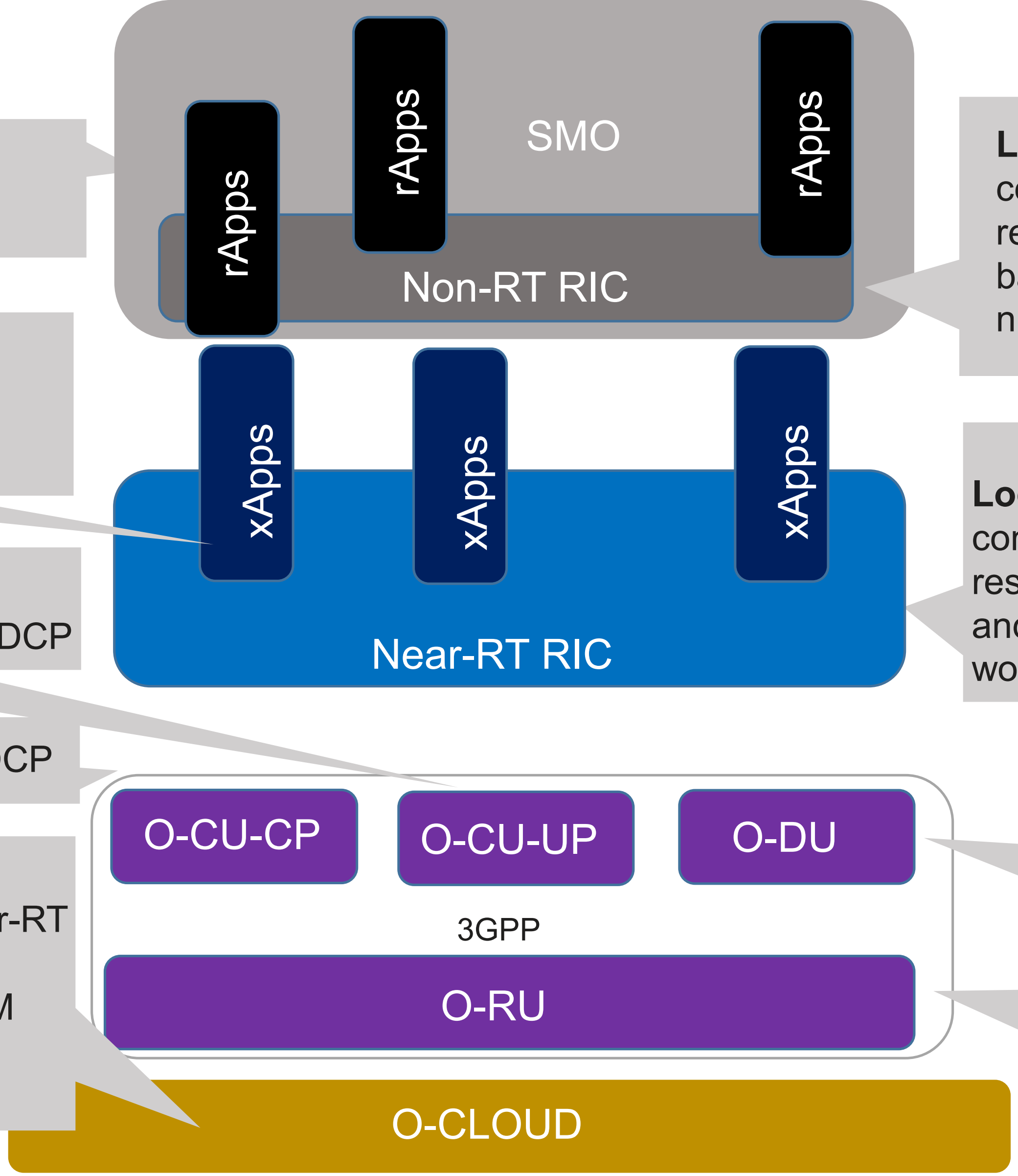
System supporting orchestration of RAN components

Application designed to run on near-RT RIC
- Independent of the near-RT RIC
- May be provided by 3rd party

Logical node hosting SDAP and UP part of PDCP

Logical node hosting RRC and CP part of PDCP

Cloud Computing platform comprising:
- PHY infra nodes to host O-RAN (e.g: near-RT RIC, O-DU.
- Supporting SW components (e.g: OS, VM monitor, Container Runtime)
- MANO functions



Logical node enabling Non-RT control/optimization of RAN elements and resources. AI/ML workflows and policy-based guidance of applications/features in nRT RIC

Logical node enabling near-RT control/optimization of RAN elements and resources vía fine-grained data collection and actions over E2. May include AI/ML workflows

Logical node hosting RLC/MAC/High-PHY layers based on LLS

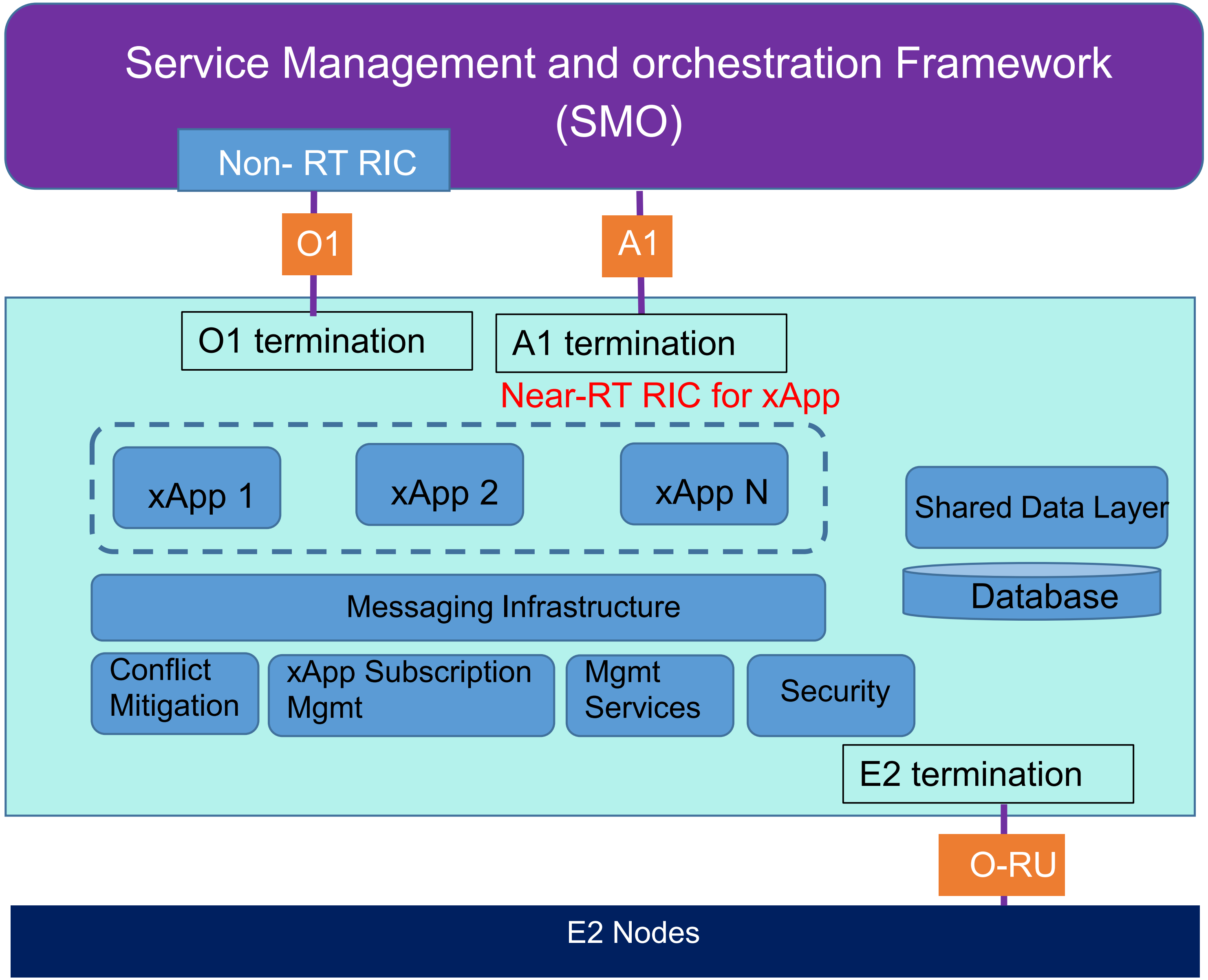
Logical node hosting low -PHY layer (FFT/WFT, PRACH extraction) and RF based on LLS

RIC O-RAN WG

WG1	UC, arch, slicing, security
WG2	Non-RT RIC, A1
WG3	Near-RT RIC, E2
WG4	Open FH (IEEE1914, eCPRI, CPRI)
WG5	Open F1, W1, E1, X2, Xn)
WG6	Cloudification and Orchestration
WG7	Whitebox reference design
WG8	Stack reference design (CU/DU)
WG9	Open X-Haul (FH, MH, BH)
WG10	OAM

https://www.o-ran.org/ecosystem Technical Priority Document (Telefonica, DT, Orange, Vodafone, TIM)

RIC – Logical Architecture



RIC Disaggregated NF

A1: policy enrichment info; model mngmt (JSON)
Policy feedback

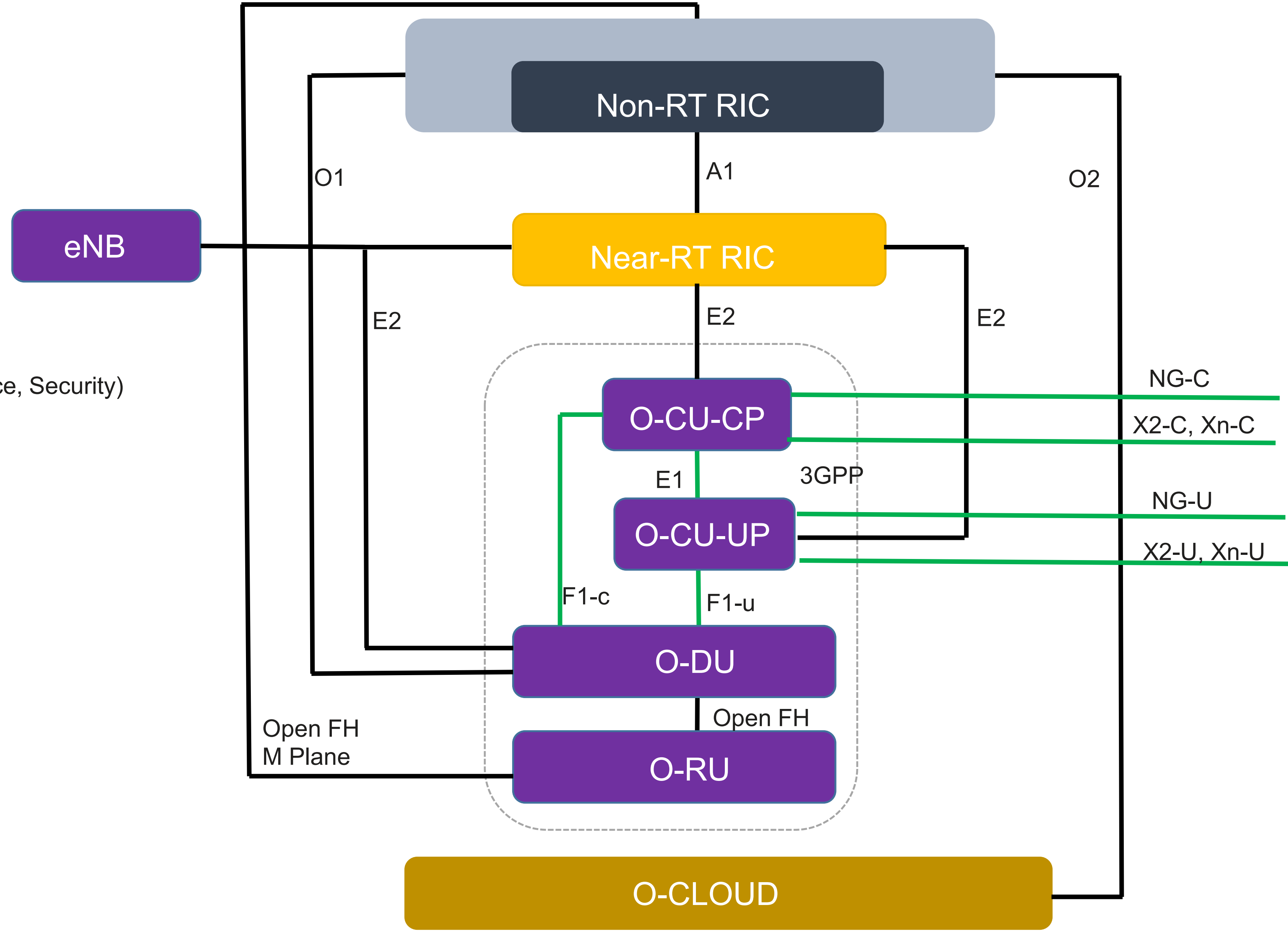
E2: based on policies comands to BS, monitor
suspend, stop, override or control via policies
Data colection and feedback

O1:FACPS (Fault, Configuration, Accounting, Performance, Security)
Performance, and updates feedback

O-FH M Plane: A1: FCAPS for O-RU
SW mngmt, CM, PM, FM, file mngmt, instalation

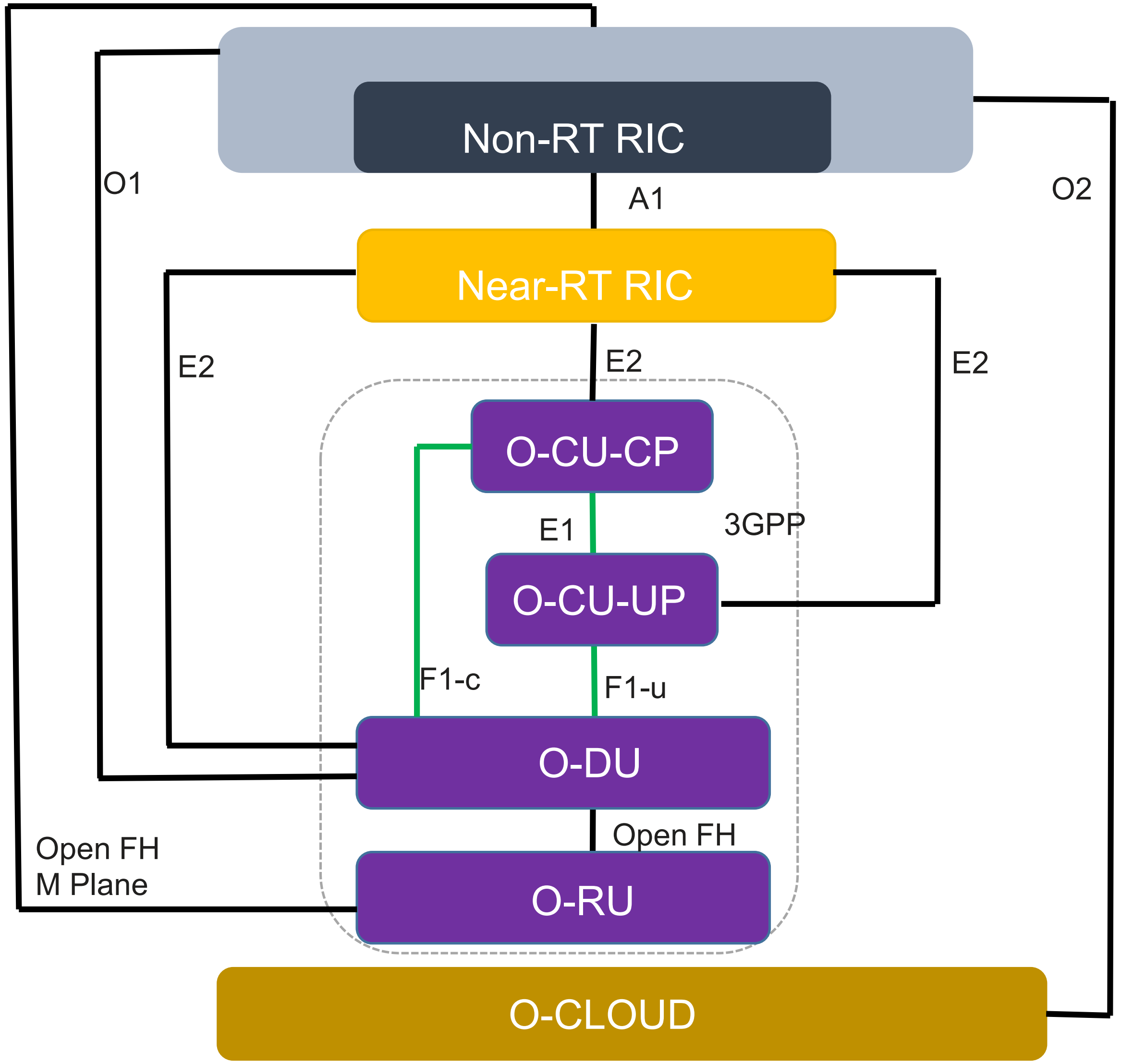
O2:
Performance resources and workload management
(scaling, FCAPS, SW mngmt, resource créate/delete)

E2 nodes

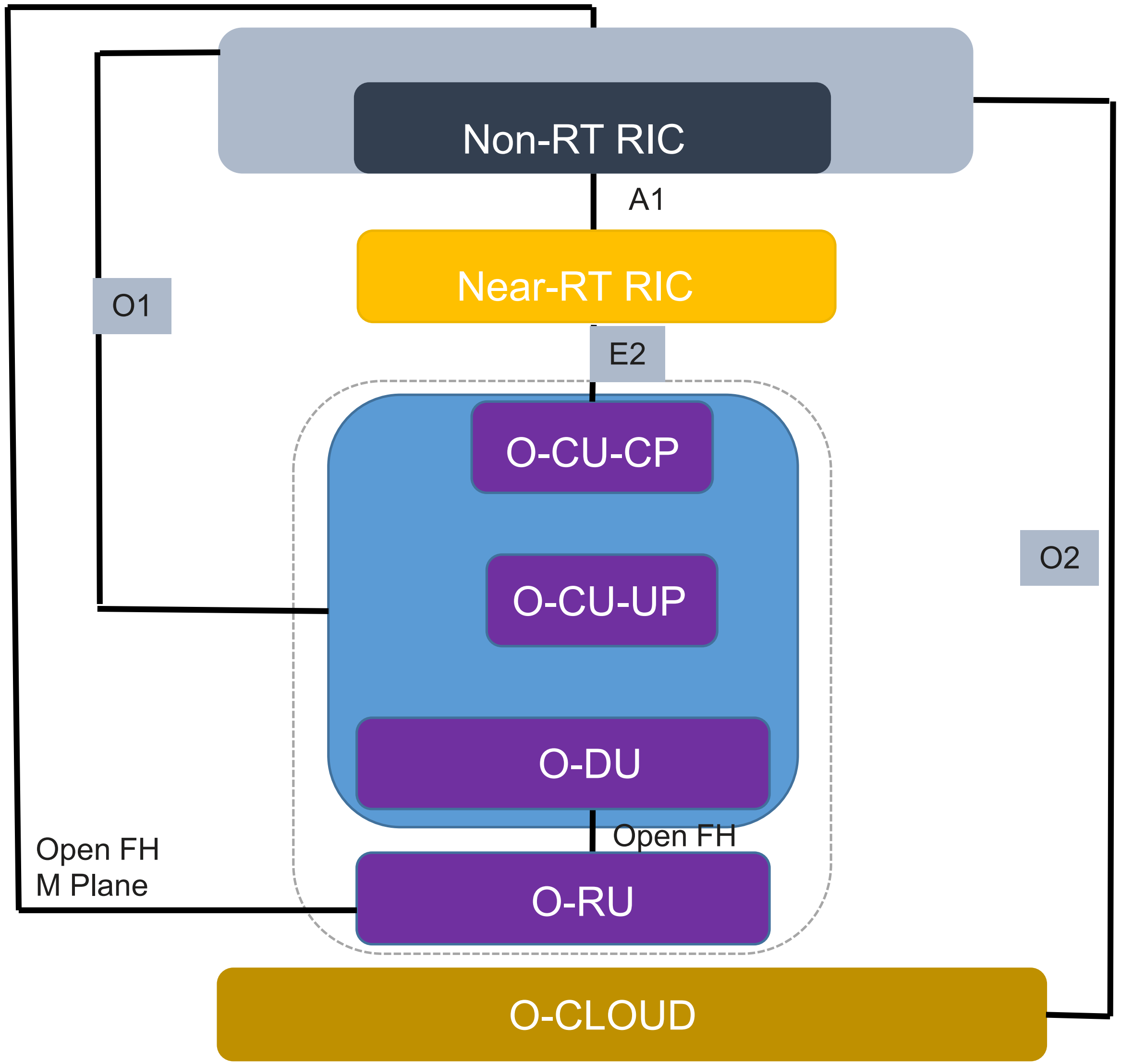


RIC Disaggregated NF

Modelo desagregado, el modelo mas agresivo



Modelo con agregación de O-CU-CP   O-CU-UP   O-DU



CePETel
Sindicato de los Profesionales
de las Telecomunicaciones

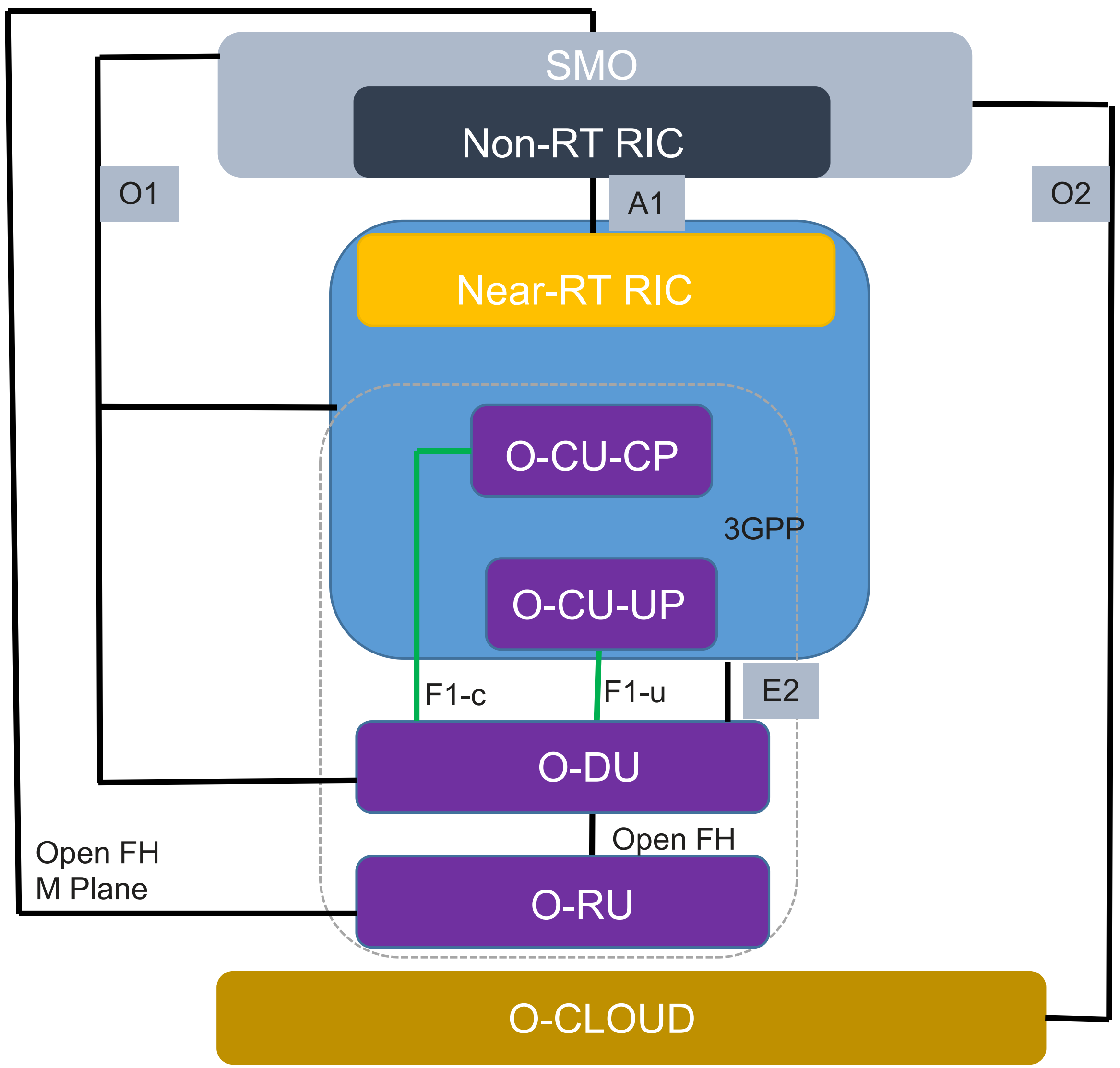
SECRETARÍA TÉCNICA

IPEI

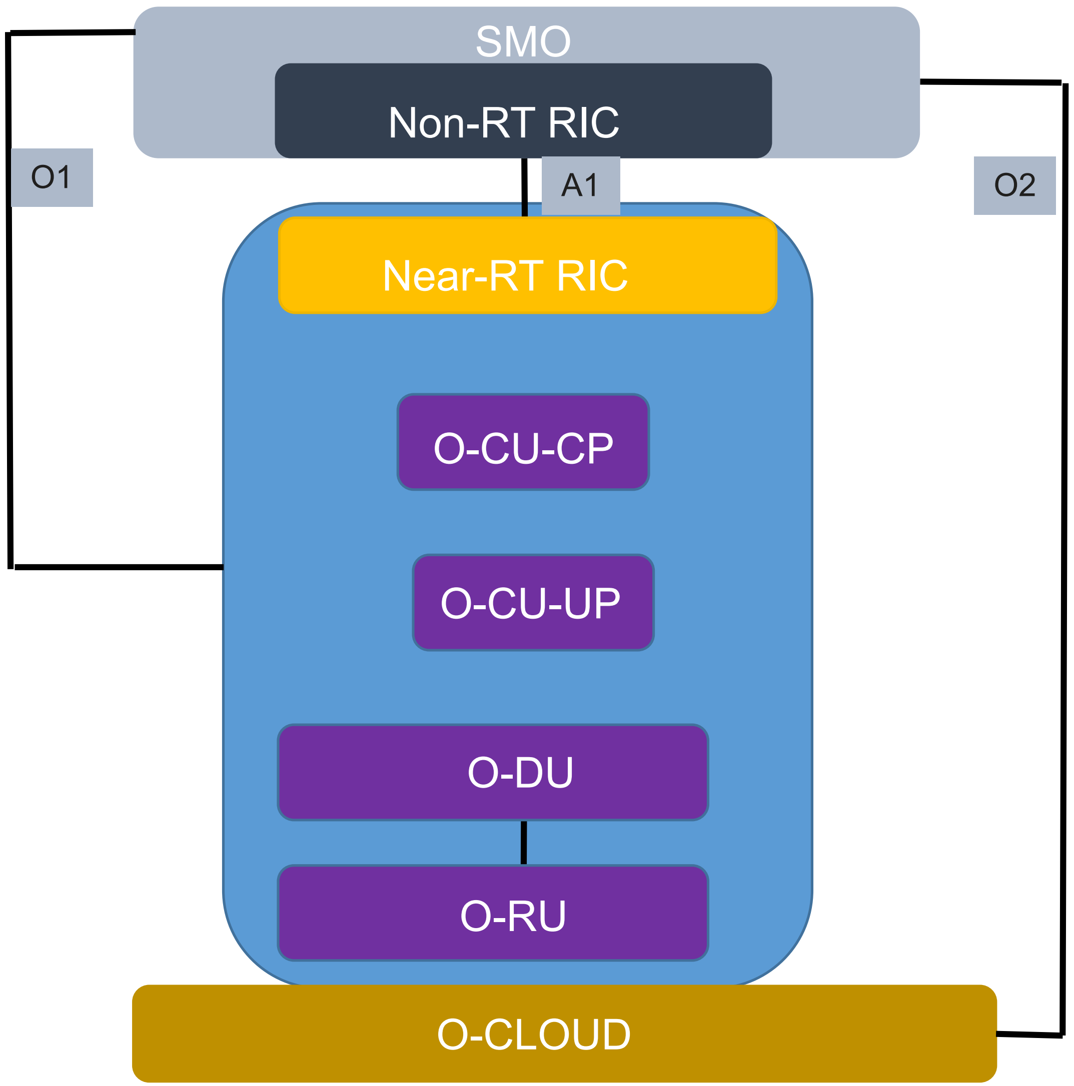
Prof. José Luis Pellegrino

RIC Disaggregated NF

Modelo con agregación de Near-RT RIC   O-CU-CP   O-CU-UP



Modelo con todos los nodos agregados



O-RAN RIC Overview

RIC is defined to enable eNB/gNB functionalities as xApps. Applications like mobility management, admission control, and interference management are available as "apps" on controller, which enforces network policies towards RAN elements.

A1 Interface:

- Policy feeback to non-RT RIC
- Policy, enrichnment info and ML

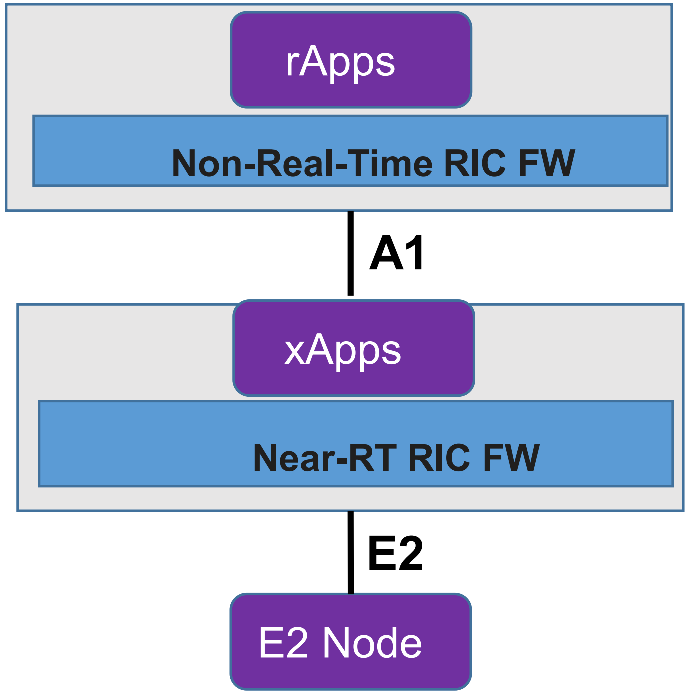
model mgmt for near-RT RIC

O1 Interface:

- Data collection and control
- FCAPS for RIC and RAN (data collection, provisioning, performance, fault mgmt)

E2 Interface:

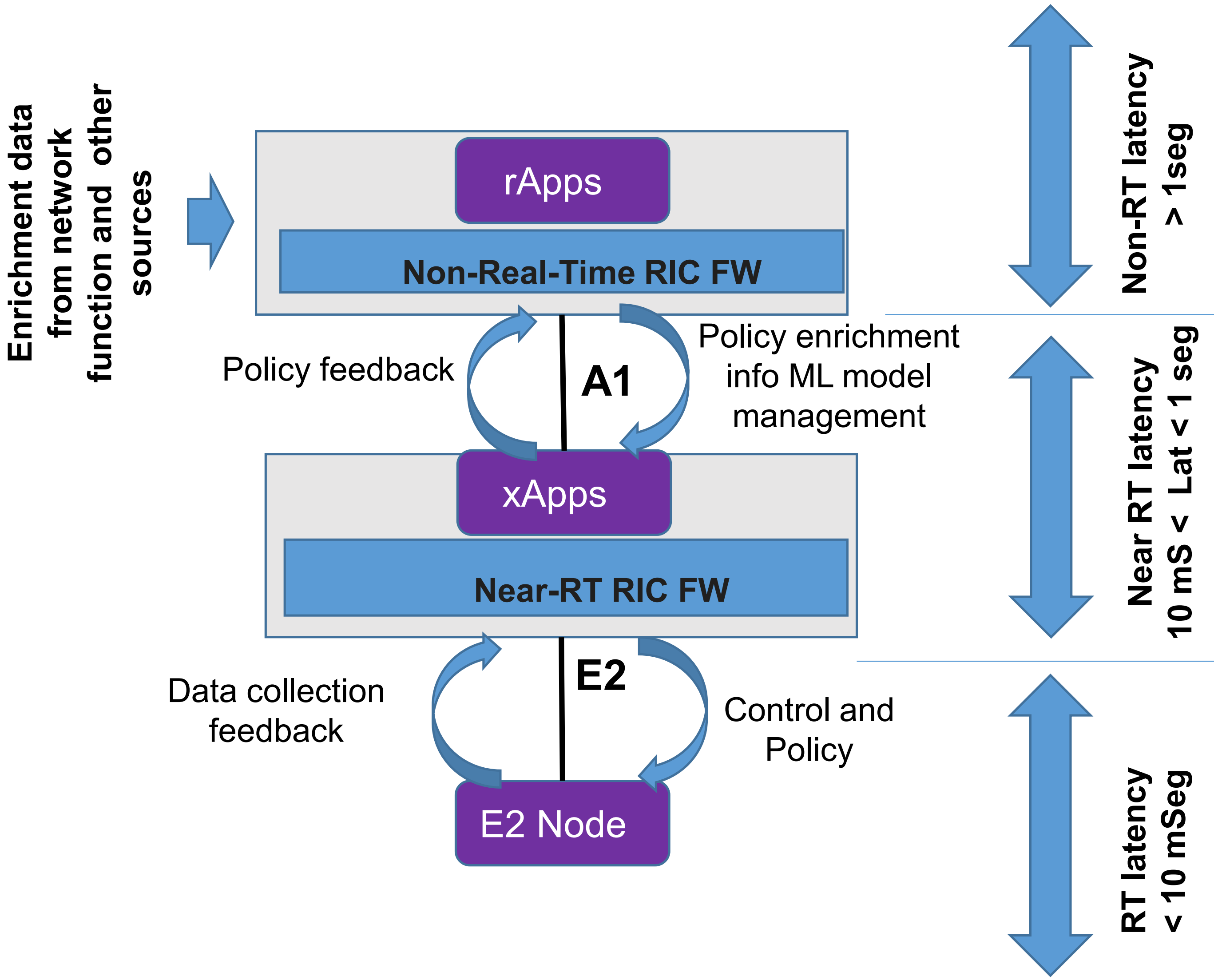
- RAN closed loop
- RIC control and policy towards RAN
- Data collection and feedback to near-RT RIC



Non-Real-Time RIC:
Provides configuration, management and analytics (visibility into network,
AI-based feeds, recommentations to near-RT RIC)
Supports non-RT intelligence RRM, higher layer procedure optimization, policy optimization in RAN, adn provides AI/ML models to near-RT RIC

Near-RT RIC:
A SW platform for a set of xApps for the RAN
Enables near-RT control and optimization of RAN elements
and resources via fine-grained data collection and actions over E2 interface
Use cases: network intelligence (policiy enforcement, HO optimization), resource assurance (radio-link monitoring, advance SON), resource control (load balancing, slicing policy)

O-RAN RIC: Functional Split & Control Loops



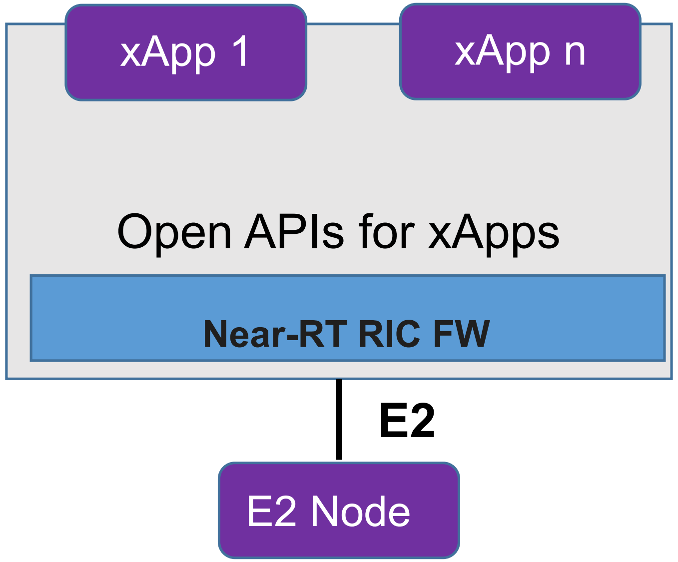
- Service and Policy mgmt
- RAN analytics
- AI/ML model training

- RAN control and optimization
- xApps for use cases
- UE and cell specific metrics (H.O)

- Real time actions
- Resource Management
- Radio scheduling, HARQ, beamforming, etc

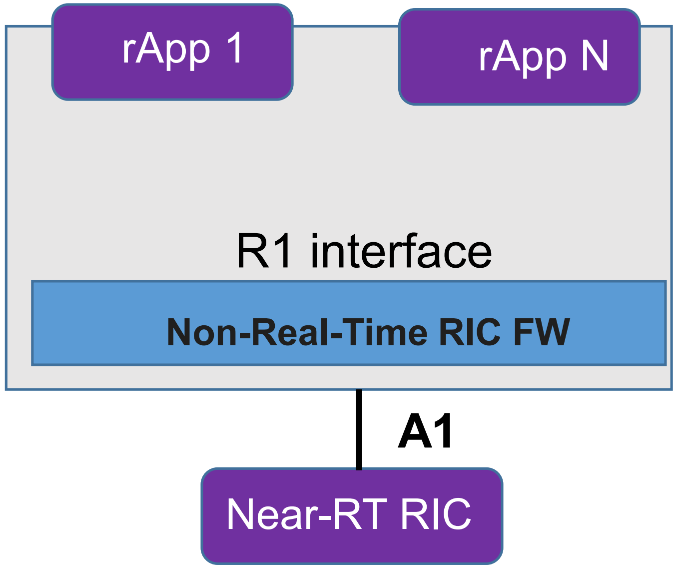
O-RAN xApps and rApps

xApps



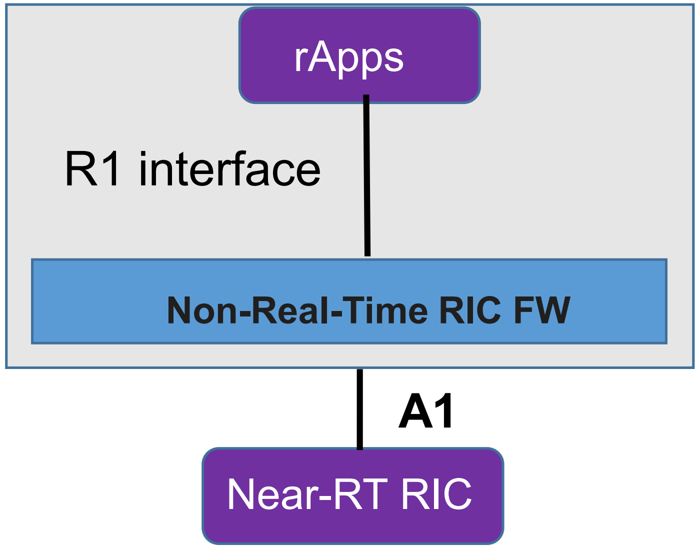
- An application designed to run on Near-RT RIC
- Runs inside RAN domain
- Likely to consist of one or more microsevices
- At point of on-boarding identifies which data it consumes and which data t provides
- Is independent at Near-RT RIC and may be provided by third party
- E2 enables a direct association between xApps and RAN functionality

rApps



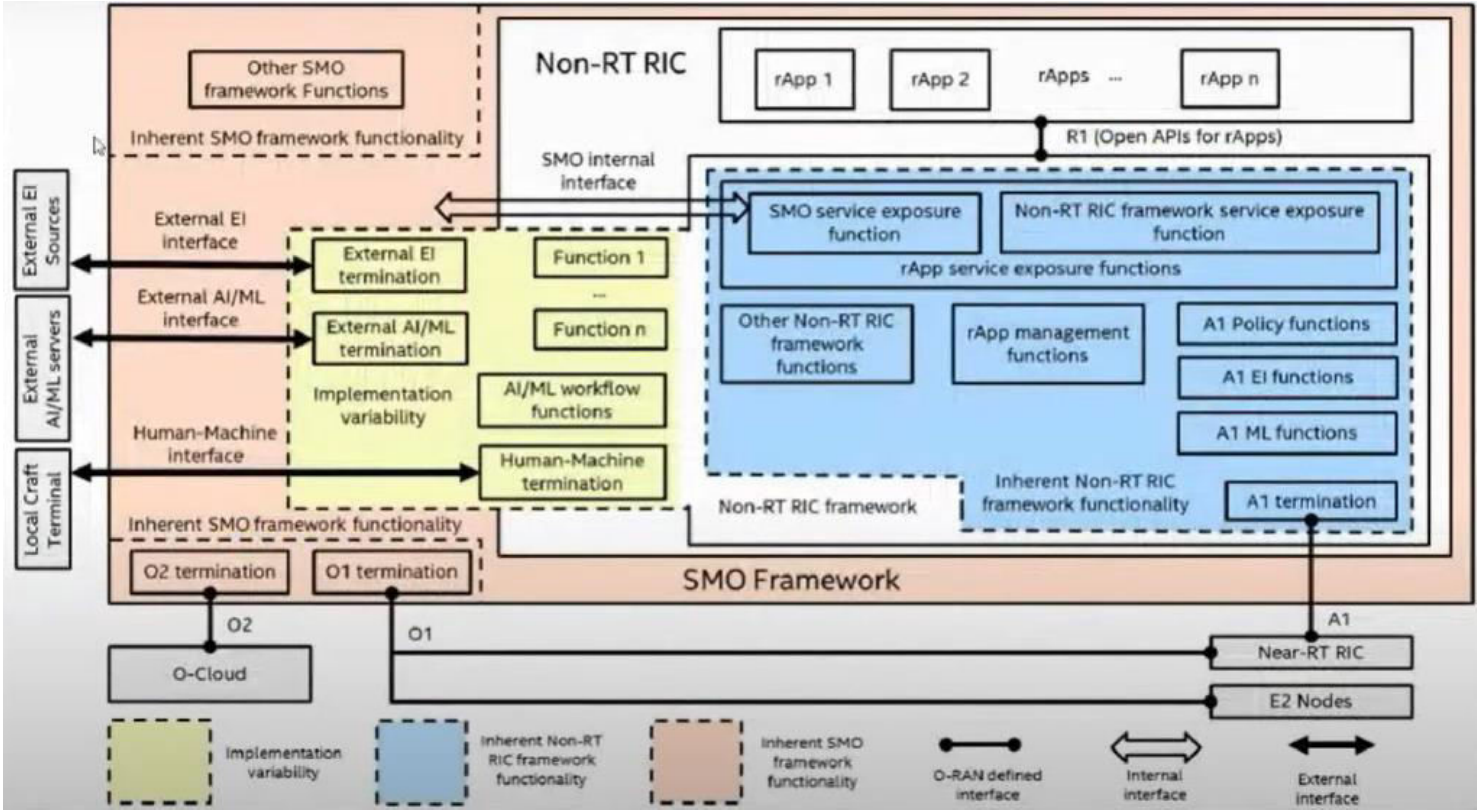
- Application designed to run on Non-RT RIC
- Runs inside de management plane
- Provide value added services (VAS) relative to intelligent RAN optimization and operation, like
  - Providing policy-based guidance and enrichment information accross A1 interface
  - Performig Data analyticsAI/ML training and interference for RAN optimization or for use of other rApps
  - Recomending configuration management actions over O1 interface

Non-RT RIC and A1 interface



- **Goal** of Non-RT RIC is to support RAN optimization by poviding **policy-based** guidance, **model management and enrichment information** to near-RT RIC function so that RAN can be optimized.
- Functionality includes: configuration management, device mgmt, mgmt for all NW elements.
- Similar to Element Management Systema (EMS) in legacy NWs
- All new radio units are self-configured by Non-RT RIC, reducing the need for manual intervention (very important in mMIMO 5G deployments and small cells.
- By providing timely insights into NW operations allows to optimize NW by applying pre-determined service and policy parameters.
- Can use data analytics and AI/ML training/interference to determine RAN optimization actions for which it can leverage SMO services such as data collection and provisioning services of O-RAN nodes.
- Trained models and RT control functions produced in Non-RT RIC are distributed to Near-RT RIC for runtime execution.

Non-RT RIC detailed functional architecture



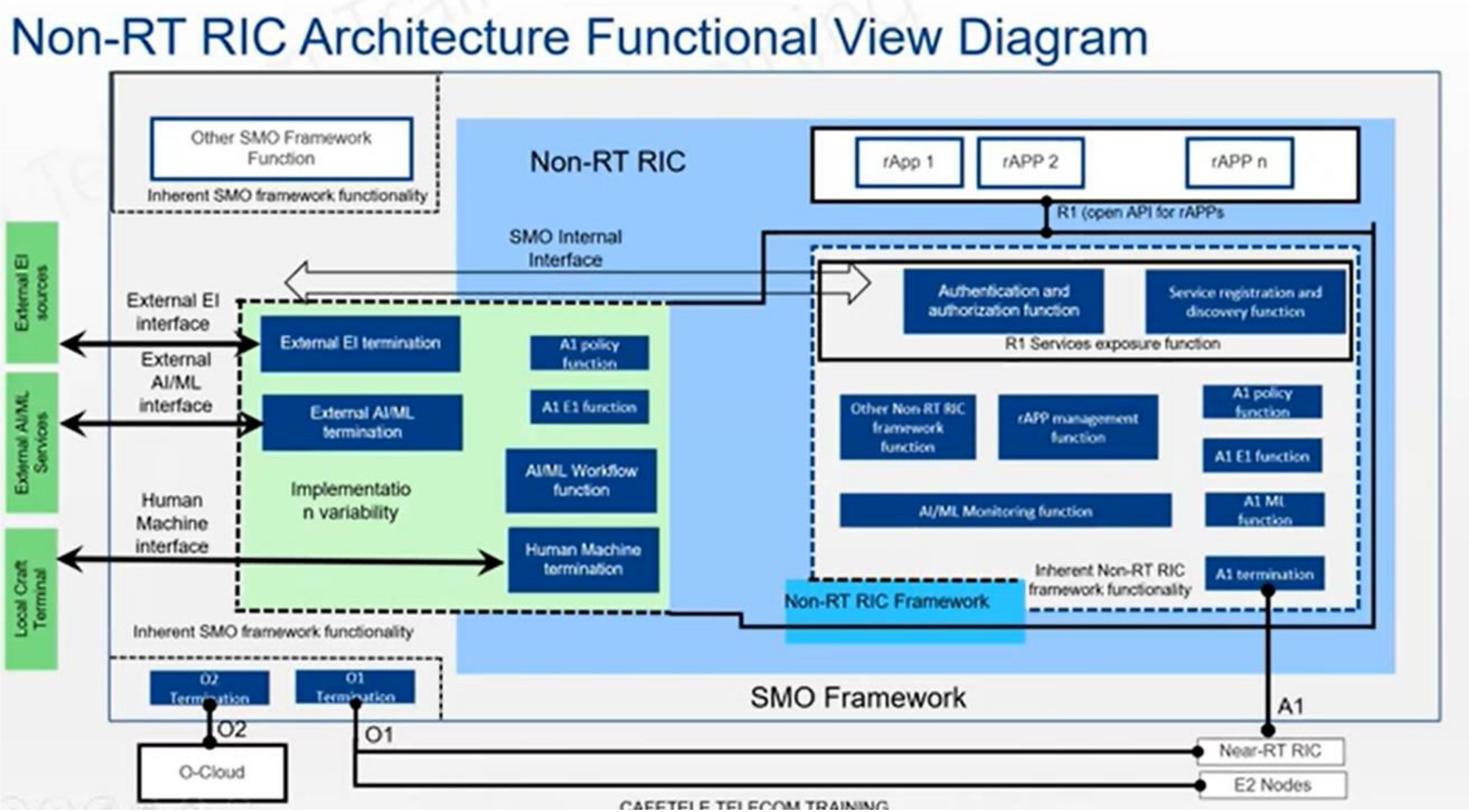
Habla con partes inherentes al Non-RT RIC FW

Habla con partes que puede o no ser inherentes al Non-RT RIC

Habla con partes que NO son inherentes al Non-RT RIC

Near-Real Time RIC

Propósito General



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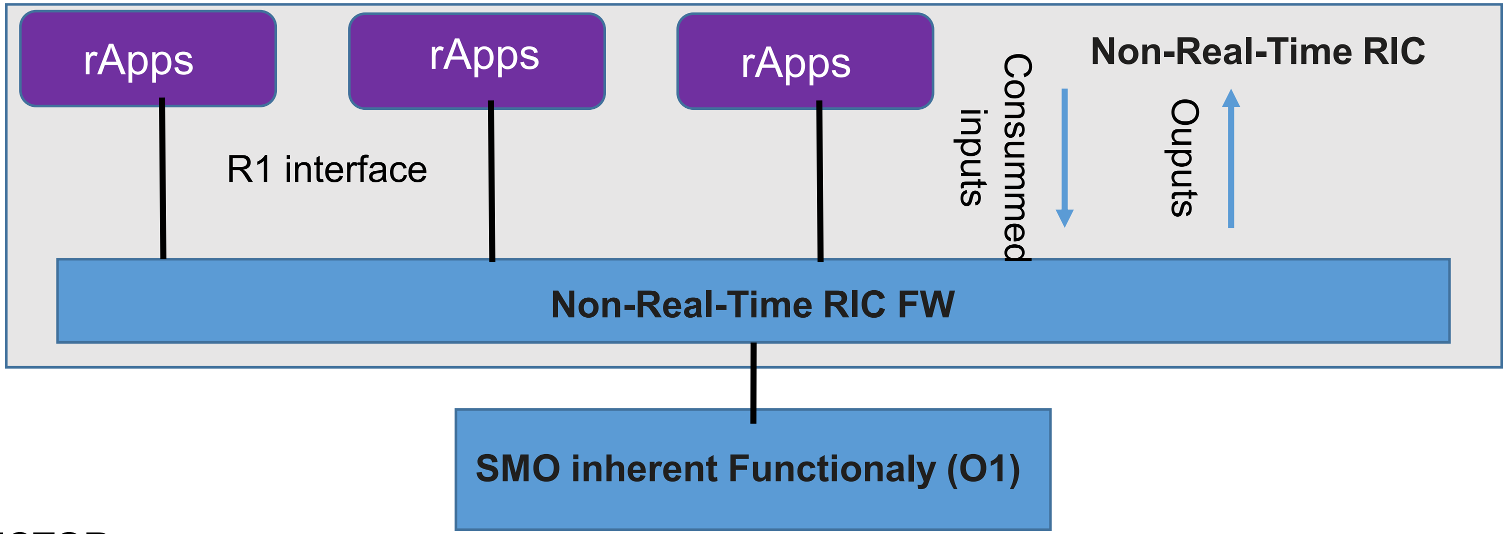
Non-RT RIC rApps examples

RF SIGNAL PREDICTOR

- It consummes O1 measurements of RF signal experienced by the UE for serving/neighbour cells, measurements for UE location
- It outputs future time prediction of RF signal at that location for serving/neighbour

CELL UTILIZATION PREDICTOR

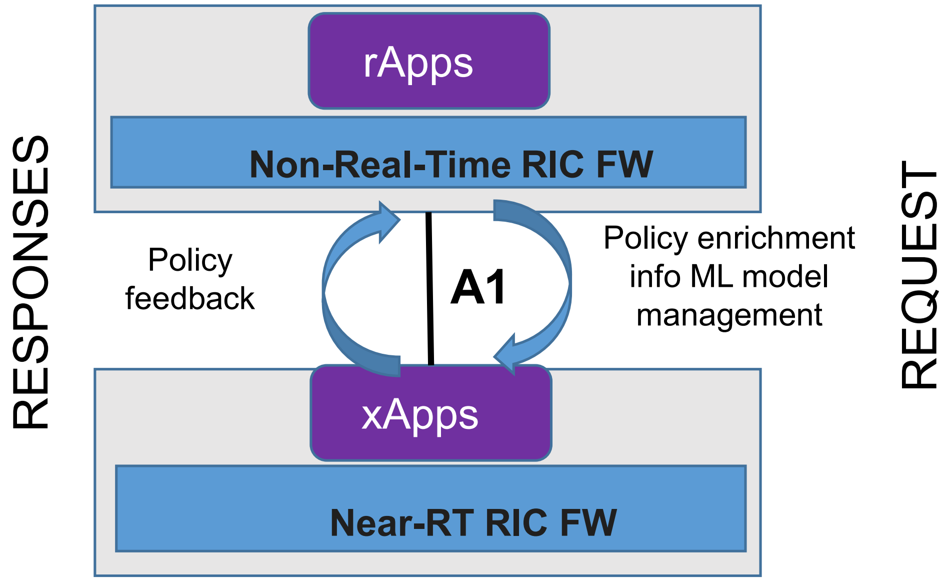
- It consummes cell utilization measurement regarding actual capacity utilization for a cell site over time
- It outputs future time prediction of the cell site utilization based on the trend (traffic in the morning vs traffic in the afternoon, etc)

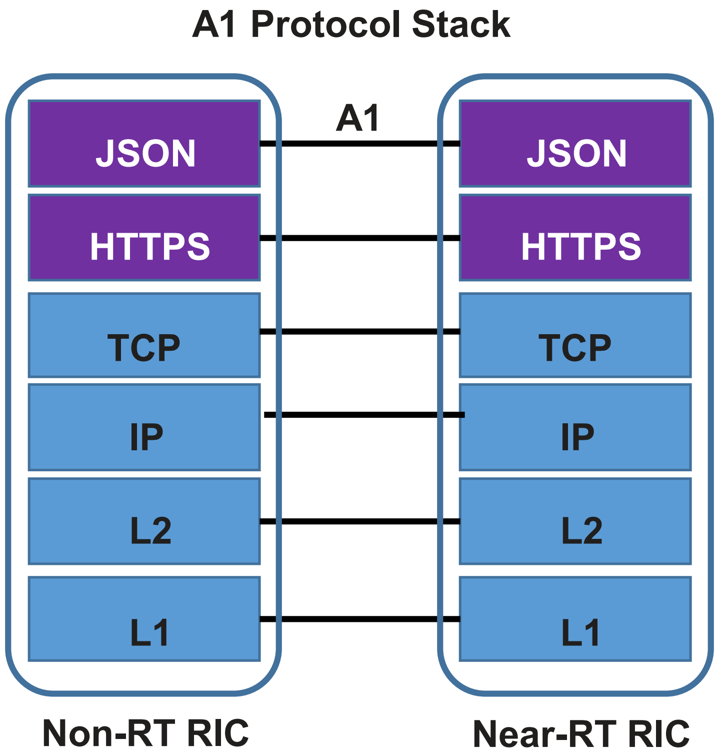


UE QoE PREDICTOR

- It consumes measurements on UE RF signal (actual RAN measurement or prediction), mesurement of cell site capacity utilization (actual or prediction).
- It calculates QoE experience by particular UE:
    - Estimates actual QoE based on actual RF signal and actual cell site
    - Estimates QoE if in neighboor cells based on actual RF signal and actual cell utilization.
    - Estimates future QoE if connected to serving/neighboor cell based on predicted signal and predicted cell utilization

Non-RT RIC A1 interface

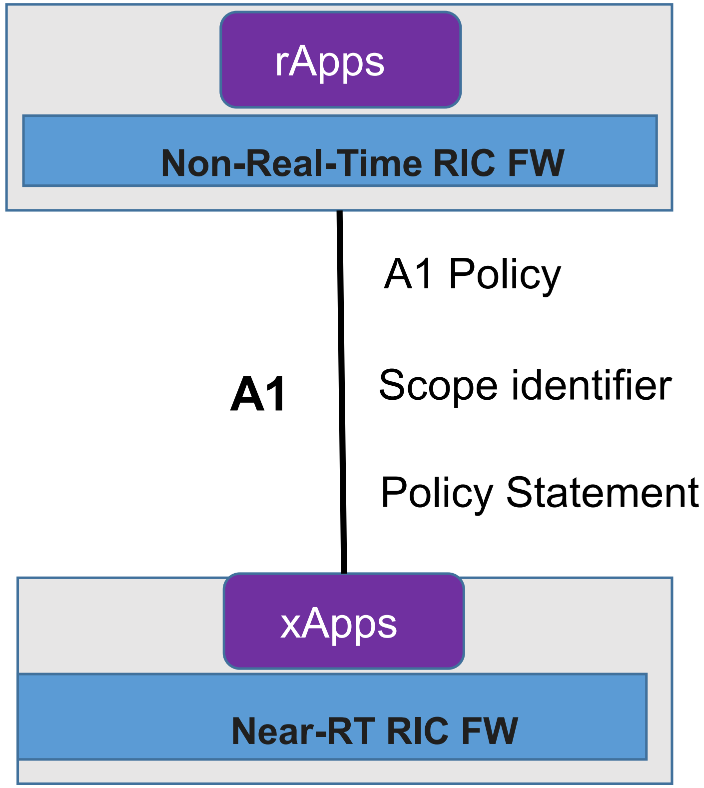




A1 Interface

- Enables non- RT RIC function to provide policy-based guidance, ML model management and enrichment information to near-RT RIC function so that the RAN can optimize RRM under certain conditions.
- Provides inter-connection of non-RT RIC functionality in **SMO domain** with near-RT RIC functionality in **RAN supplied by different manufacturers**
- Provides policies for individual UEs or groups of UEs
- Provides basic feedback on policy state from near-RT RIC that enables non-RT RIC to monitor use of policies
- Provides enrichment information as required by near-RT RIC

Non-RT RIC A1 Policies



A1 Policy:
identified by a policy identifier (Policy Id) assigned by non-RT RIC

Scope ID:
It represents policy statements to be applied (e.e UEs, QoS flows, or cells), Identifier for a single UE (ueid), groups of Ues (groupid), slice (sliceid), QoS (qosid), cell (cellid)

Policy Statement:
It represents the directives to near-RT RIC and covers policy objectives and policy resources

RAN operation can be optimized using A1 policies that:

- Are not critical to traffic
- Have temporary validiy
- Handle individual UE or dynamically defined groups of Ues
- Act within and takes precedence over the configurations
- Is non-persistent, i.e. does not survive a restart of the near-RT RIC

Non-RT RIC- JSON

JSON es un formato de estructurar datos (como lo es xml por ejemplo)
Tiene dos elementos:

-Propiedad: “nombre”, “id”, “ueId”, “qosId”

-Valor

```
{
“propiedad”: valor,
“propiedad”: valor
}
```

Non-RT RIC A1 Policies examples

QoS bases resource optimization per-UE

{
        “scope”: {
          “ueId”: ”855”,
          qosId”: “68”
        },
          “qosObjectives”: {
          “priority level”: 50
        }
}

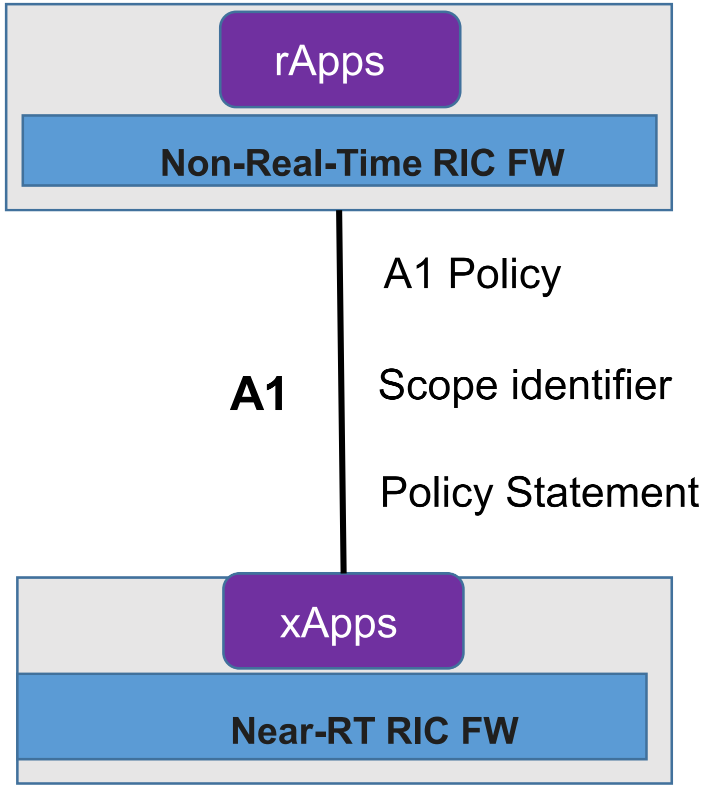
QoS bases resource optimization per-slice

{
        “scope”: {
          “sliceId”: ”10”,
          “qosId”: “68”
          “cellId”: “22”
        },
          “qosObjectives”: {
          “gfbr”: 1000
          “mgfbr”: 400
          “pdb”: 120
        }
}

Non-RT RIC A1 Policies examples

Traffic steering per-UE

```
{
        “scope”: {
          “ueId”: ”855”
        },
          “tspResources”: {
          {
             “cellIdList”: {
                “39”,
                “40”
                },
             “preference”:”PREFER”,
          }
          {
             “cellIdList”: {
                “41”,
                “42”
                },
             “preference”:”FORBID”
          }
  }
}
```



Traffic steering per-Slice

```
{
        “scope”: {
          “slice”: ”8”,
          “qosId”: “43”
        },
          “tspResources”: {
          {
             “cellIdList”: {
                “39”,
                “40”
                },
             “preference”:”SHALL”,
          }
          {
             “cellIdList”: {
                “41”,
                “42”
                },
             “preference”:”AVOID”
          }
  }
}
```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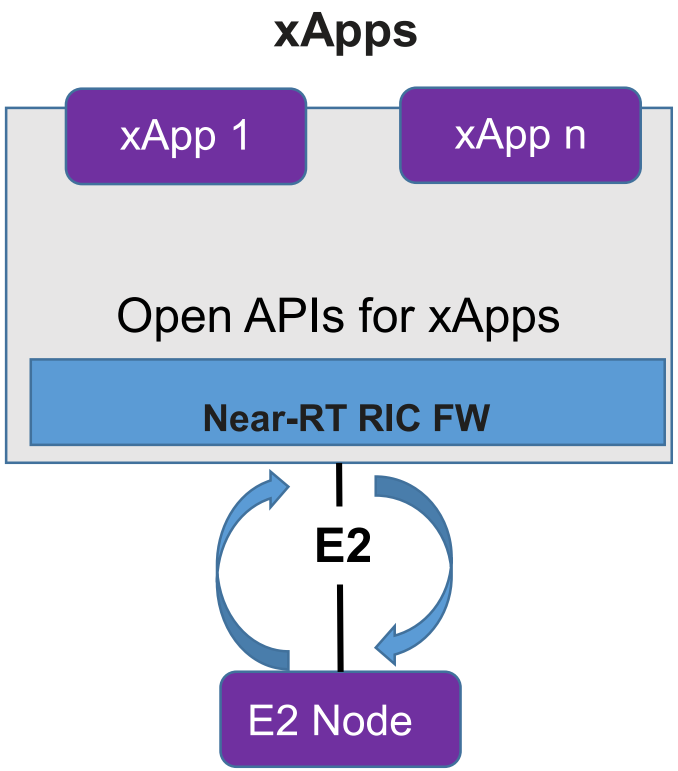
Real Time RIC E2 Policies examples



Near-RT RIC uses A1 and O1 for management and Optimization of RAN and is responsible for necessary **optimization-related tasks** across different RANs, utilizing available RAN data from all RAN types (macro, small, massive MIMO nodes).
xApps use E2 interface to collect near RT information (on a UE or cell basis)
Controls over E2 nodes is steered via policies and data provided via A1 from Non-RT RIC.

RRM functional allocation between Near-RT RIC and E2 node is subject to the capacity of E2 node and is controlled by Near-RT RIC.

Near-RT RIC may **monitor, suspend/stop, override or control** node via Non-RT RIC enabled policies.

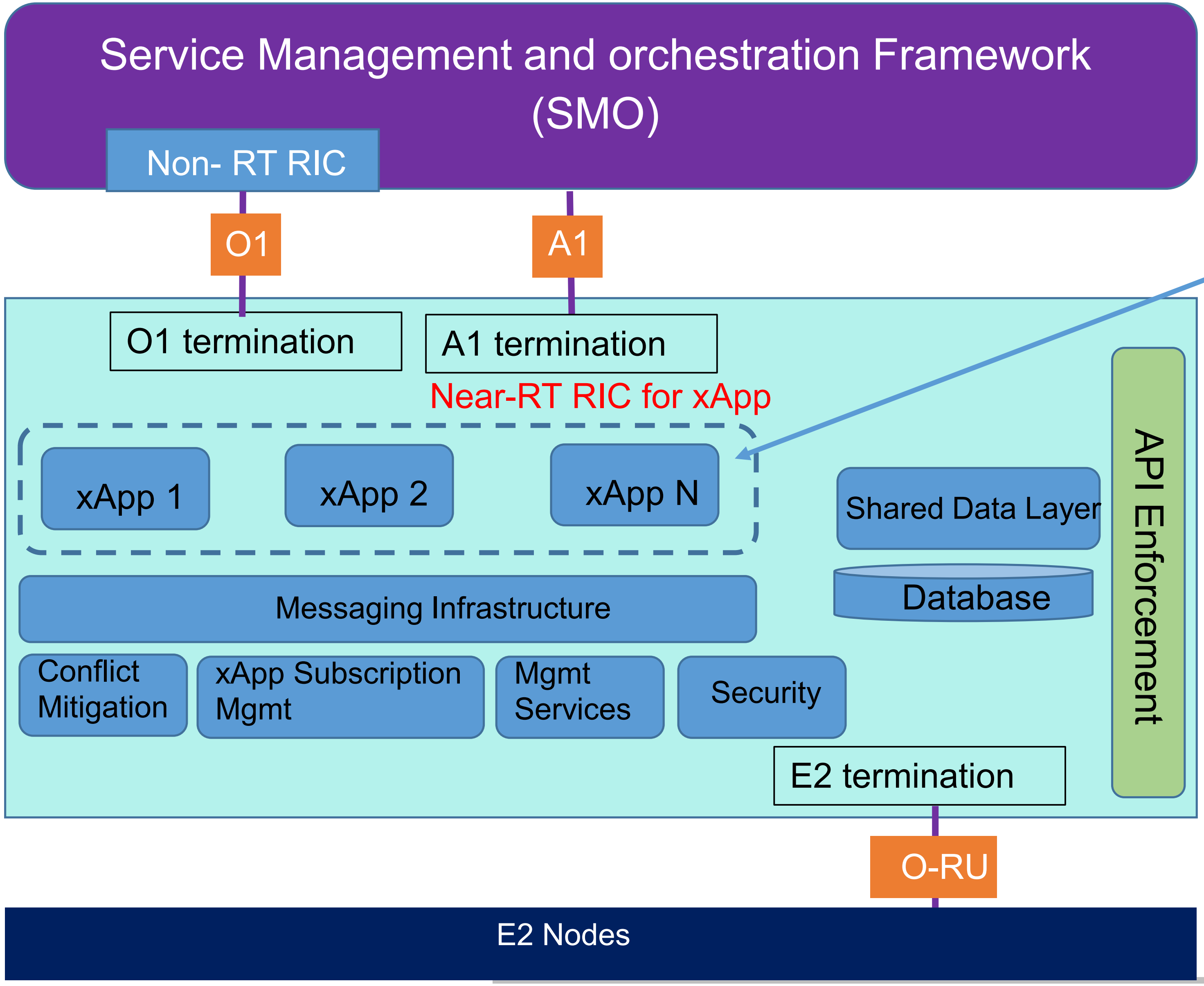
In the event of a Near-RT RIC failure, E2 Node shal be able to provide services, but there may be an outage for certain VAS provided using Near—RT RIC.

Leverages embebed inteligence and is responsibe for per-UE controlled load-balancing RB management, intrference detection and mitigation.

Radio-Network Information Base (R-NIB) captures near RT state of underlyeing network and feeds RAN data to train AI/ML models, to be fed to Near-RT RIC to facilitate RRM.

Interacts with Non-RT RIC via A1 interface to receive trained models and execute them to mprove network conditions

Near-Real Time RIC



xApp
Performs the enforcement of RRM capabilities of Near-RT RIC,Data Monitoring and parameter RAN function

Propósito General

xApps

xApps realiza funciones mejora el RRM, las capacidades N-RT RIC, monitoreo de datos y funciones de parametrización

Servicios de Gestión

Gestión de fallas

Gestión de configuración

Lleva a cabo los servicios que provee al SMO

Ciclo de vida de las xApps

- Onboarding (almacena descriptores)
- Deployment (obtiene nombre y otra info de la xApp)
- Gestión de recursos (monitorea latencia, etc)
- Terminación de xApp (libera recursos)

Near-RT RIC Internal Architecture

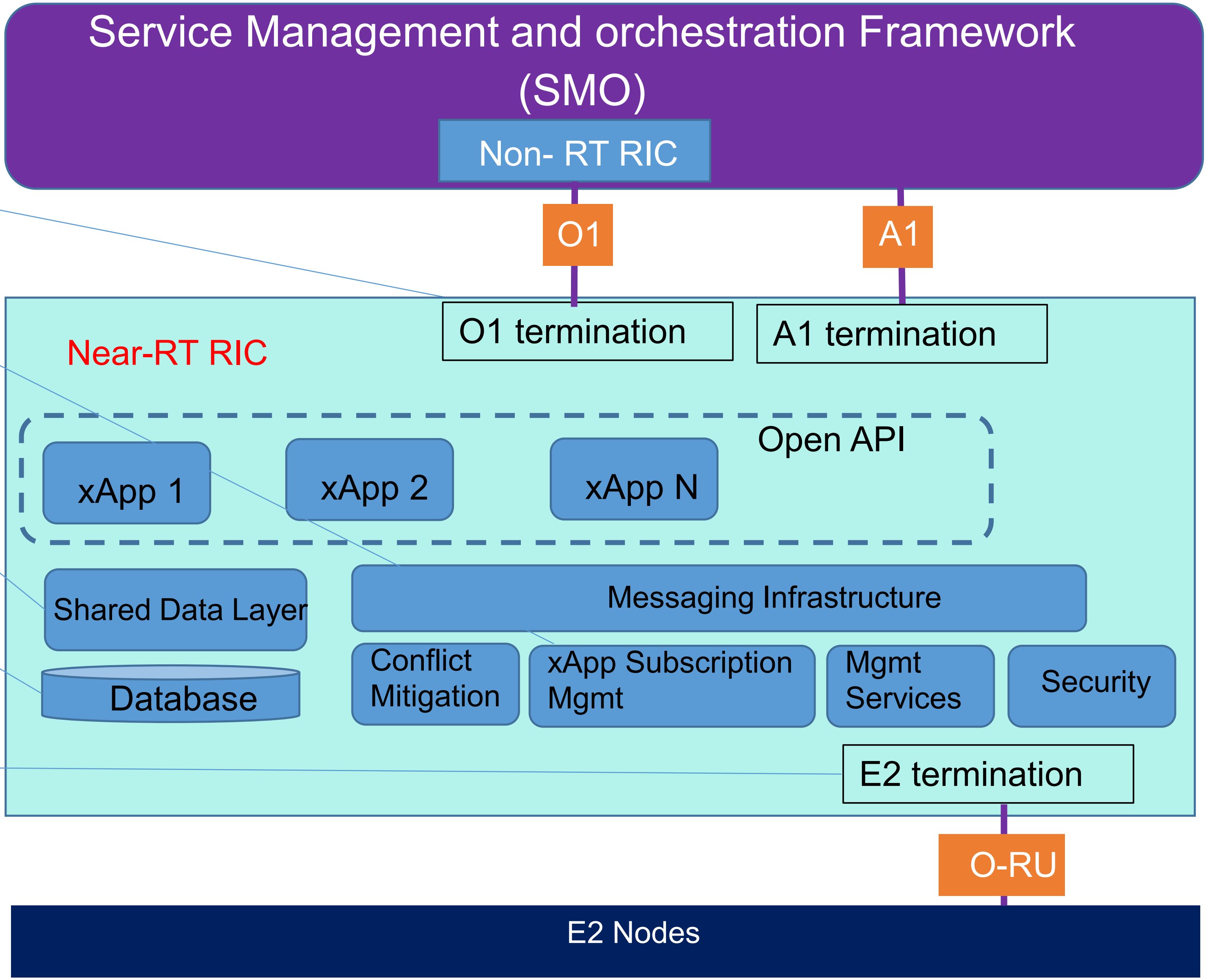
Terminates O1 interface from SMO layer and forwards management messages to Near-RT RIC management function.

Merges subscriptions from different xApps and provides unified data distribution to xApps.

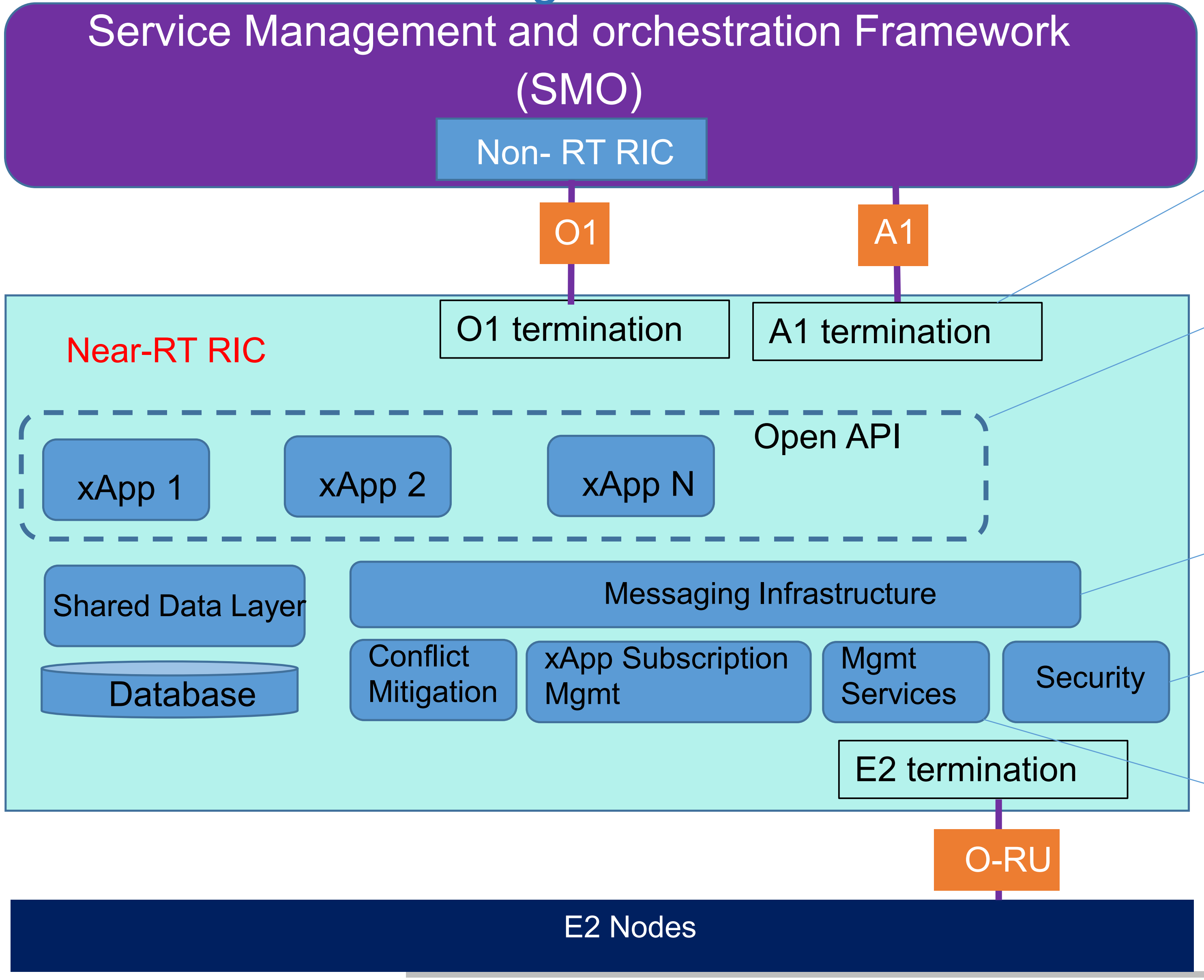
R/W of RAN/UE information

Captures near-RT state of understanding network and feeds RAN data to train AI/ML models.

Terminates E2 interface from E2 Node
Routes xApps-related messages to target xApps
Routes non xApp-related messages to E2 Manager.



Near-RT RIC Internal Arcghitecture



Terminates A1 interface from Non-RT RIC and forwards A1 messages.

Allow RRM control functionalities to be executed at Near-RT RIC and enforced in E2 Nodes. Initiates xAPpp-related transactions over E2. Handles xApp-related responses from te E2.

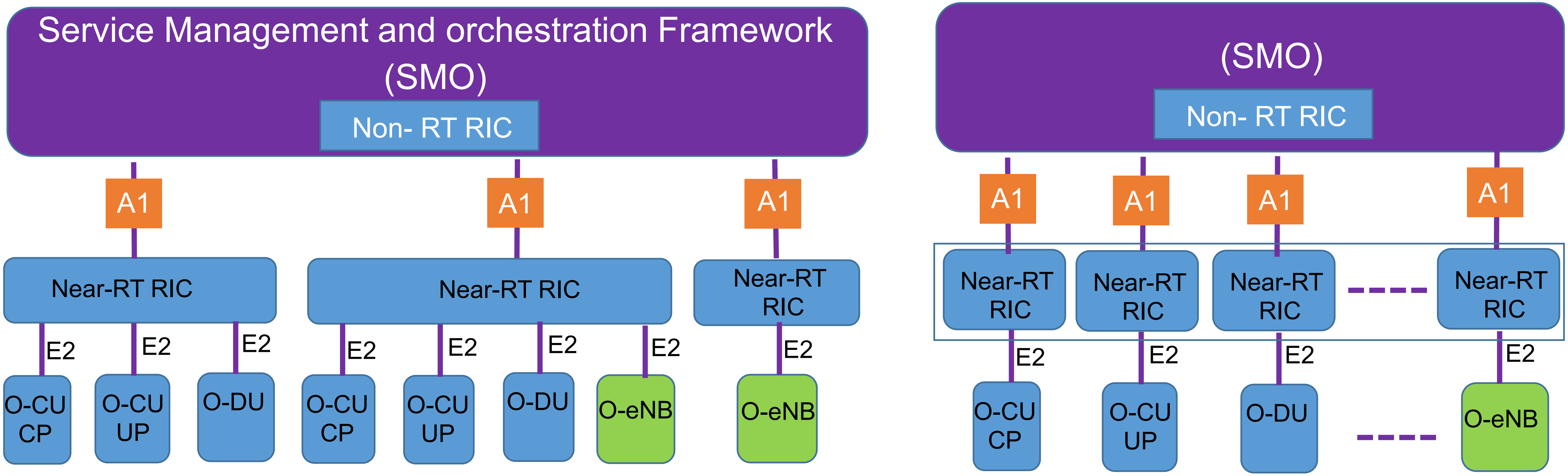
Message interaction among Near-RT RIC internal functions.

Security scheme for xApps.

Fault, confiiguration management, and performance management
Lif-cycle management of xApps
Logging tracing and metrics collection and transfer to external system for evaluation

Near-Real Time RIC Implementation Options

Distributed O-Cu CP



DEFINICIONES

Near-RT RIC (O-RAN Near-real-time RAN Intelligent Controller): a logical function that enables near-real-time control 8 and optimization of RAN elements and resources via fine-grained (e.g. UE basis, Cell basis) data collection and actions 9 over E2 interface. 10
Non-RT RIC(O-RAN Non-real-time RAN Intelligent Controller): a logical function that enables non-real-time control 11 and optimization of RAN elements and resources, AI/ML workflow including model training and updates, and policy-12 based guidance of applications/features in Near-RT RIC. 13
O-CU: O-RAN Central Unit: a logical node hosting RRC, SDAP and PDCP protocols. 14
O-CU-CP: O-RAN Central Unit – Control Plane: a logical node hosting the RRC and the control plane part of the PDCP 15 protocol. 16
O-CU-UP: O-RAN Central Unit – User Plane: a logical node hosting the user plane part of the PDCP protocol and the 17 SDAP protocol. 18
O-DU: O-RAN Distributed Unit: a logical node hosting RLC/MAC/High-PHY layers based on a lower layer functional 19 split. 20
O-RU: O-RAN Radio Unit: a logical node hosting Low-PHY layer and RF processing based on a lower layer functional 21 split. This is similar to 3GPP’s “TRP” or “RRH” but more specific in including the Low-PHY layer (FFT/iFFT, PRACH 22 extraction). 23
O-eNB (O-RAN eNB): an eNB [10] or ng-eNB [11] that supports E2 interface.

Llevamos el Acceso al Core o el Core al Acceso?

DEFINICIONES

O1: Interface between orchestration & management entities (Orchestration/NMS) and O-RAN managed elements, for 25 operation and management, by which FCAPS management, Software management, File management and other similar 26 functions shall be achieved. 27
SMO: Service Management and Orchestration system. 28
A1: Interface between Non-RT RIC and Near-RT RIC to enable policy-driven guidance of Near-RT RIC 29 applications/functions, and support AI/ML workflow. 30
E2: Interface connecting the Near-RT RIC and one or more O-CU-CPs, one or more O-CU-UPs, and one or more O-DUs. 31
E2 Node: a logical node terminating E2 interface. In this version of the specification, ORAN nodes terminating E2 32 interface are: 33
- for NR access: O-CU-CP, O-CU-UP, O-DU or any combination as defined in [4]; 34
- for E-UTRA access: O-eNB. 35

xApp: An application designed to run on the Near-RT RIC. Such an application is likely to consist of one or more 36 microservices and at the point of on-boarding will identify which data it consumes and which data it provides. The 37 application is independent of the Near-RT RIC and may be provided by any third party. The E2 enables a direct association 38 between the xApp and the RAN functionality. 39
O-Cloud: O-Cloud is a cloud computing platform comprising a collection of physical infrastructure nodes that meet O-40 RAN requirements to host the relevant O-RAN functions (such as Near-RT RIC, O-CU-CP, O-CU-UP, and O-DU), the 41 supporting software components (such as Operating System, Virtual Machine Monitor, Container Runtime, etc.) and the 42 appropriate management and orchestration functions.

AI ML
Datos de la propia radio
Controlar y optimizar el comportamiento de la radio via control msg o policy msgs

The near-RT RIC is subproject of the ORAN software community (https://o-ran-sc.org), working closely with O-RAN alliance. Many other O-RAN SC projects in O-RAN scope.
The source code is under https://gerrit.o-ran-sc.org/r/W/admin/projects/ or https://gerrit.o-ran-sc.org/r/admin/repos/q/filter:ric

All Sw based on code developed by Nokia and AT&T, Samsung and HCL contributios started in summer 2020.

The exact list of components that make up the near-RT RIC platform: https://wiki.o-ran-sc.org/pages/viewpage.action?pageId=10715416