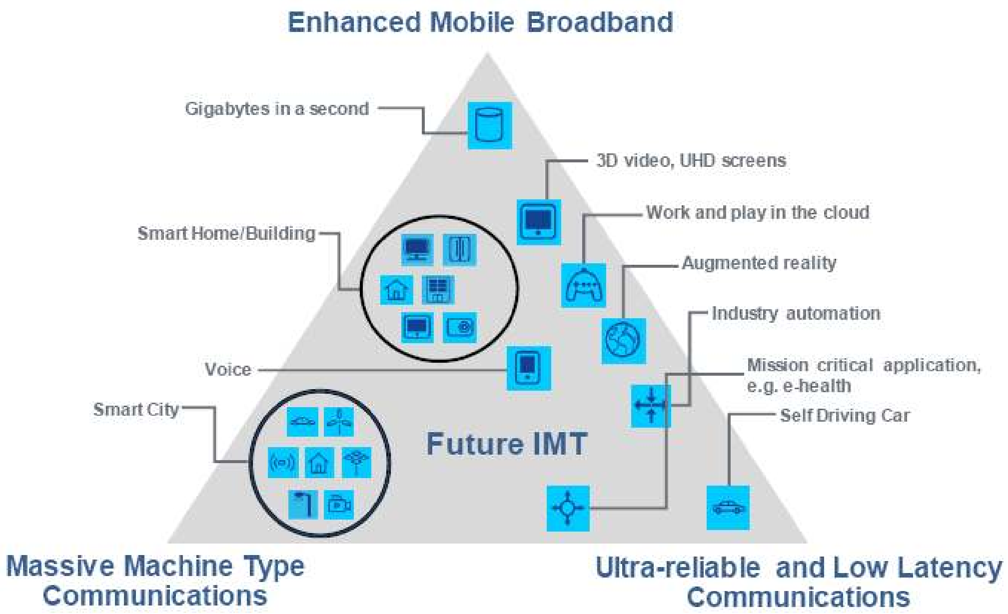
AZ 5G BEVEZETÉSE MILYEN KIHÍVÁSOKAT JELENT AZ ÁTVITELTECHNIKAI HÁLÓZATOK FEJLESZTÉSÉBEN?

LIFE IS FOR SHARING.

TARTALOM

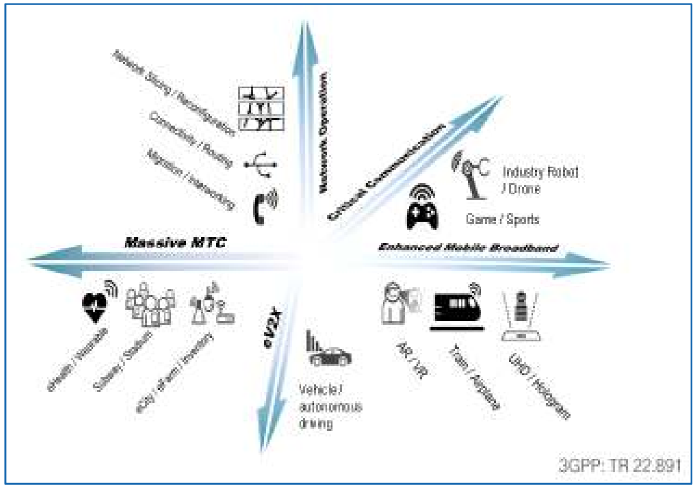
BEVEZETÉS
5G VÍZIÓ

5G szolgáltatások



5G hálózat jellemzői

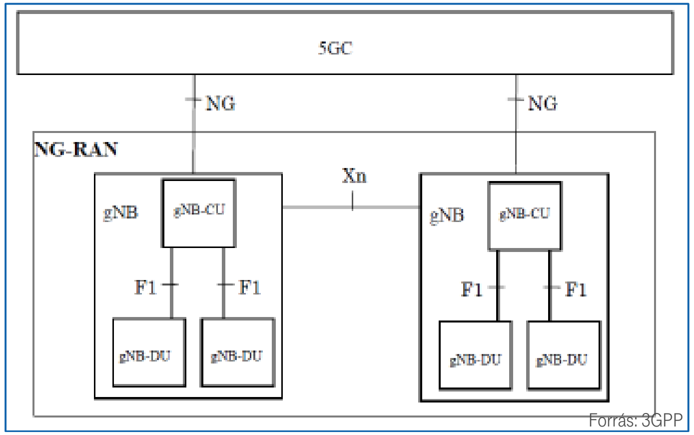
- Kis késleltetés, rugalmas hálózat
- Mesterséges intelligencia, automatizált hálózat
- Kiterjesztett (AR) /virtuális (VR) valóság
- Vertikális ipari alkalmazások
- Moduláris architektúra
- Szolgáltatás alapú E2E hálózat szegmentálás

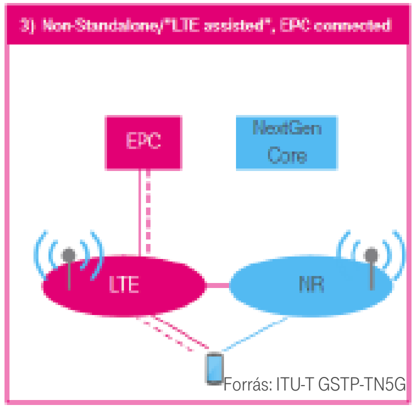


Forrás:
ITU-R M.2083-0 IMT-2020

5G RAN ARCHITEKTÚRA
ÉPÍTŐ ELEMEK

5GC/NC:	Core hálózat
NG:	Interfész a RAN és Core között
gNB/NR:	5G bázisállomás / New Radio
gNB-CU:	Central Unit
gNB-DU:	Distributed Unit
F1:	Interfész a CU és DU között
Xn:	Interfész a szomszédos gNB-k között



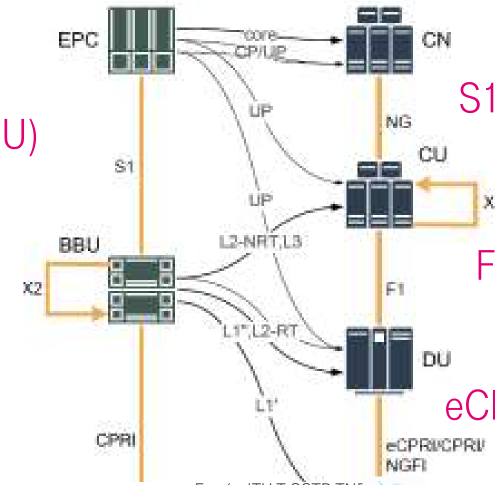


Első evolúciós fázis – LTE támogatott architektúra
4G és 5G közös (NSA)helyszín (Option 3)

5G RAN ARCHITEKTÚRA

4G FUNKCIÓ SZÉTVÁLASZTÁS -> ÚJ INTERFÉSZEK

EPC UP egyrésze ⇨ Central Unit (CU) & Distributed Unit (DU)
BBU non-realtime L2 & L3 része ⇨ Central Unit (CU)
BBU real-time L2 része ⇨ Distributed Unit (DU)
BBU L1 része ⇨ Remote Radio Unit (RRU)

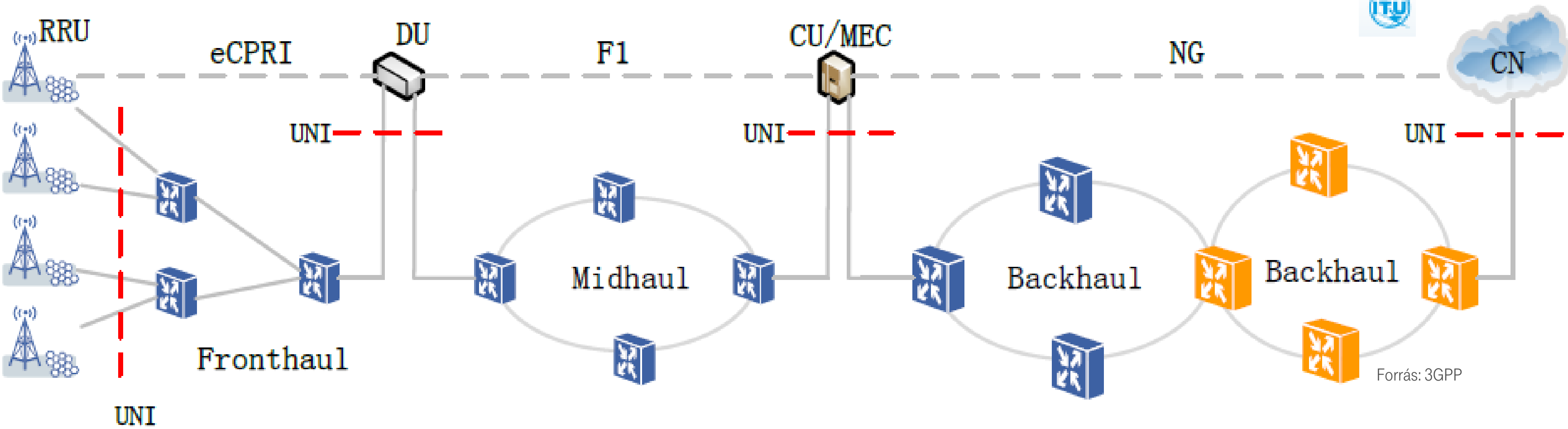


S1/NG Backhaul

F1 Midhaul

eCPRI/CPRI Fronthaul

Forrás: ITU-T GSTP-TN5



Forrás: 3GPP

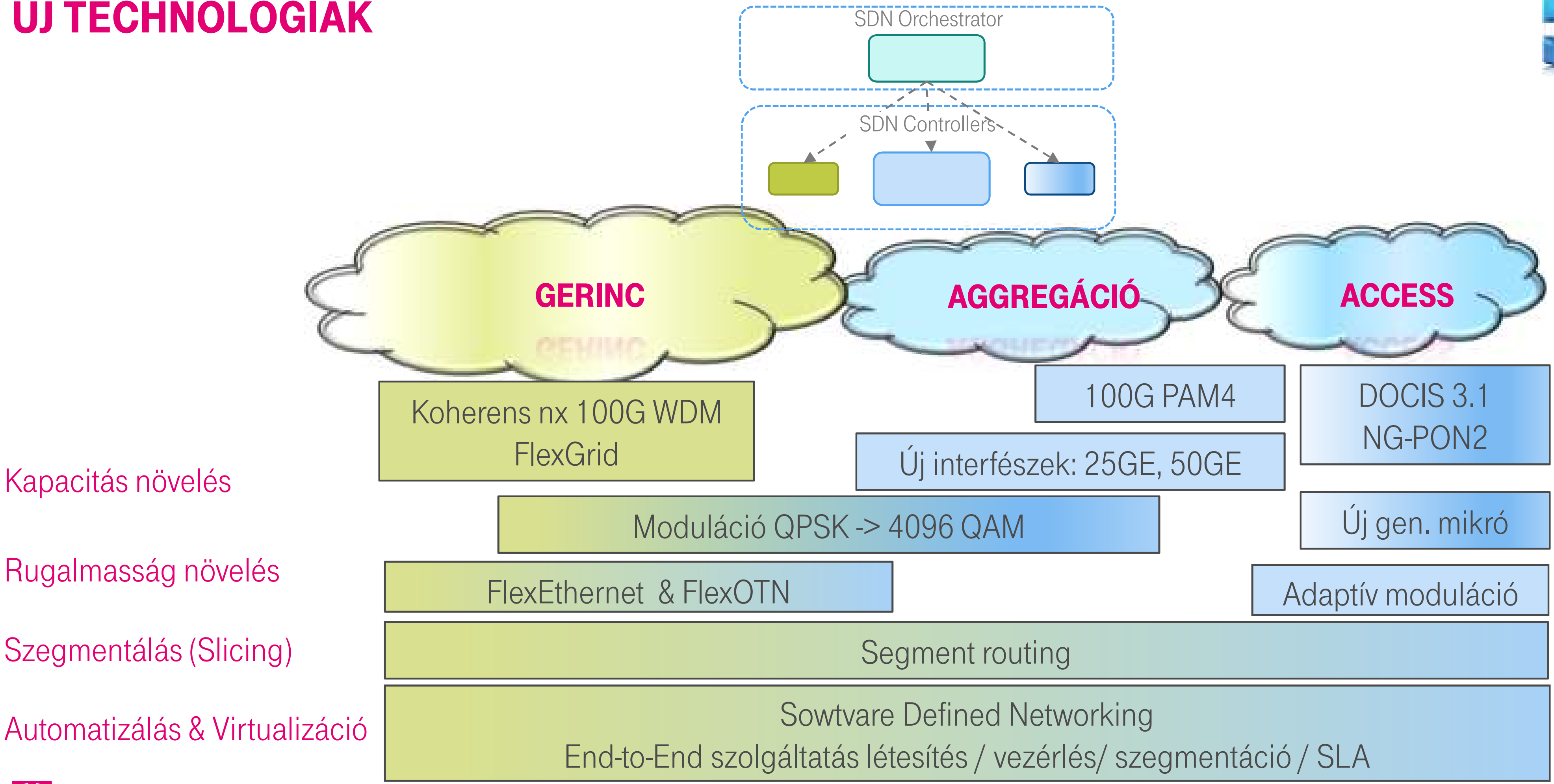
Forrás:
Technical Report ITU-T GSTP-TN5G

ÁTVITELTECHNIKAI KÖVETELMÉNYEK

Profile	Protocol	Bandwidth	Security	Delay	Jitter	Freq. sync	Time sync
Backhaul EPC/5GC – CU	S1/NG Ethernet	DL: 4 Gbps UL: 3 Gbps	IPsec	< 8 ms eMBB < 1 ms for uRLLC	NA	Radio interface: ±50ppb BS backhaul interface: ±16ppb	FDD: NA TDD (30KHz subcarrier): 1,5 µs TDD (120 KHz SC): 0,4 µs uRLLC: nx100ns Positioning: 1 µs High accuracy positioning: ~130 ns
Midhaul CU– DU Split-RAN	F1 Ethernet	DL: 5 Gbps UL: 4 Gbps	IPsec	< 8 ms eMBB < 1 ms for uRLLC	< 5% of delay		
Coordination eNB/gNB – gNB (neighboring)	X2/Xn Ethernet	DL: 4 Gbps UL: 3 Gbps	IPsec	< 5 ms	NA		
Fronthaul DU – RRU	eCPRI Ethernet	DL: 20-25 Gbps UL: 20-25 Gbps	IPsec MACsec	<100µs	< 5% of delay		
Fronthaul BB – RF (RRH) not splitted RAN	CPRI	DL: 236 Gbps UL: 236 Gbps	NA	<100µs	< 2% of delay		
Crosshaul (X-haul) DU – DU (neighboring) E-RAN* Coordination	E5 Ethernet	DL: 4 Gbps UL: 3 Gbps	MACsec	< 60 µs (E-RAN)	NA		

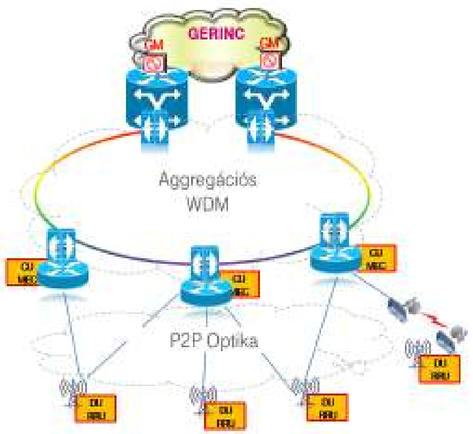
EPC: Evolve Packet Core
5GC: 5G Core
CU: Centralized Unit
DU: Distributed Unit
RRU: Remote Radio Unit (Beamforming+Radio+Antenna)
RRH: Remote Radio Head (Radio+Antenna)
BB: Baseband unit
E-RAN*: Elastic RAN (E/// proprietary solution)

VÁLASZ A KIHÍVÁSOKRA
ÚJ TECHNOLÓGIÁK

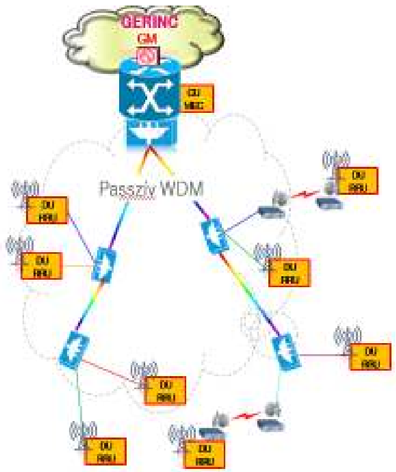


5G BÁZISÁLLOMÁSOK ELÉRÉSI LEHETŐSÉGEI

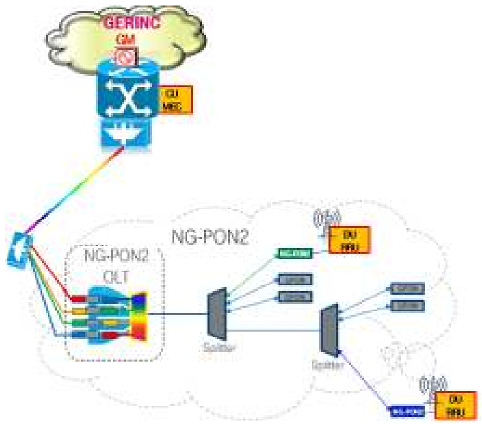
WDM Aggregáció



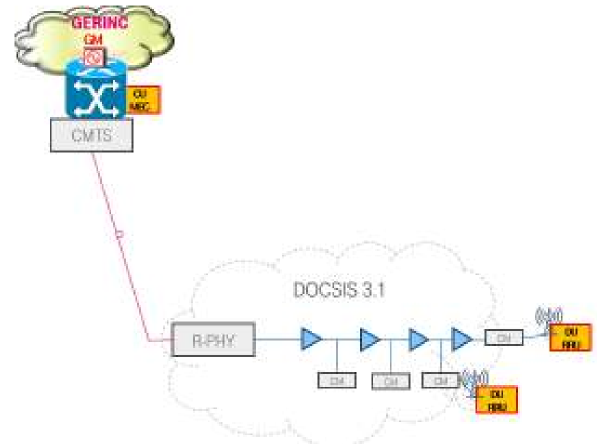
Passzív WDM



NG-PON2

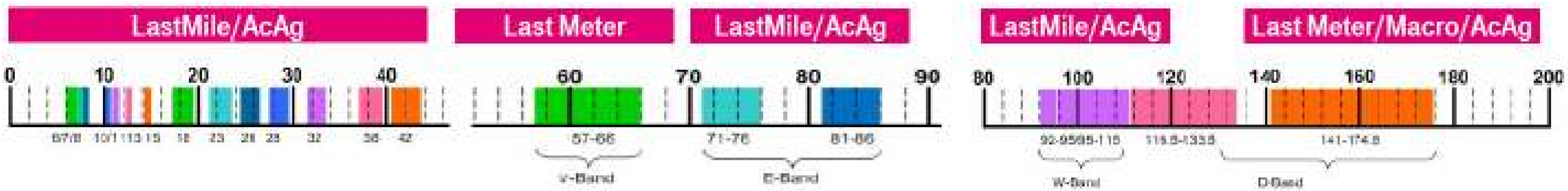


DOCSIS 3.1



Access Technológia	Letöltési bitsebesség [Gbps]	Feltöltési bitsebesség [Gbps]	Tipikus távolság [km]
P2P optika	1 -100	1 -100	20 - 120
Passzív WDM	1 -100	1 -100	20 - 80
NG-PON2	10 - 40	10 - 40	~20
DOCSIS 3.0	1,2	0,34	~40
DOCSIS 3.1 (FDX)	5	5	~40
MW 6 - 13 GHz	0,8	0,8	> 20
MW 18 - 42 GHz	1	1	2 -10
MW 80GHz (E-band)	10	10	< 1,5

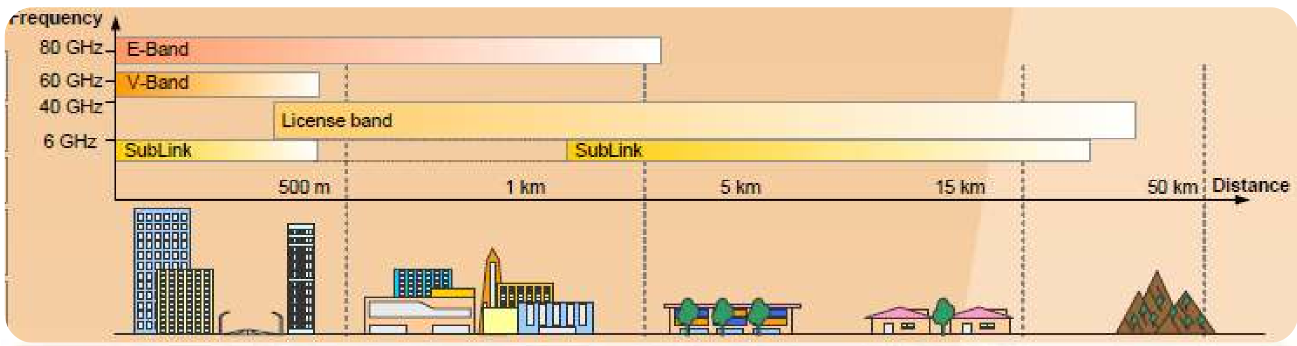
5G BÁZISÁLLOMÁSOK ELÉRÉSI LEHETŐSÉGEI
ÚJ GENERÁCIÓS MIKRÓ ALKALMAZÁSA



Frekvencia spektrum	6 -15 GHz	18 - 42 GHz	60 GHz	70 - 80 GHz	100 - 150 GHz
Csatornasáv	~ 750MHz	~ 2,2 GHz	~ 7 GHz	~ 10 GHz	~ nx 10 GHz
Kapacítás	0,8Gbps	1Gbps	nx 1Gbps	10Gbps	nx 10Gbps

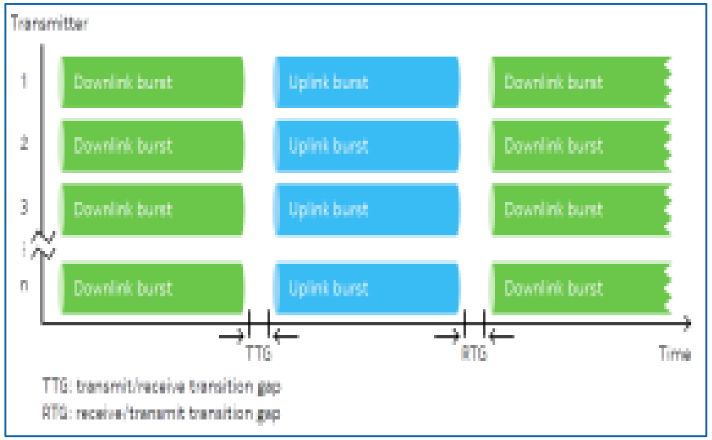
Mikróhullámú technológiák fejlődése:

- Moduláció növelés: 4 QAM -> 4096 QAM
- Kapacitás növelés:
  - Kettős polarizálással (XPIC)
  - Rádió linkek összefogásával (bonding)
- Megbízhatóság javítás:
  - Dual-band
  - Adaptív modulációval

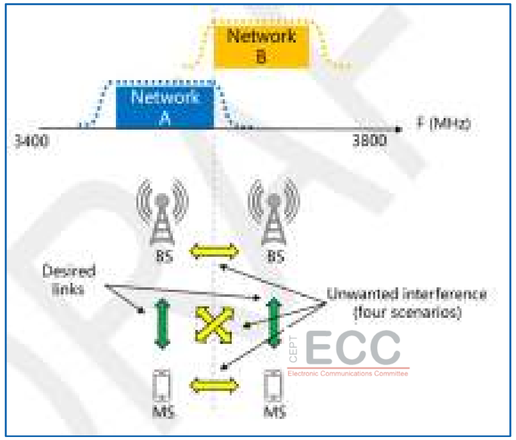


FÁZIS SZINKRONIZÁCIÓ FONTOSSÁGA

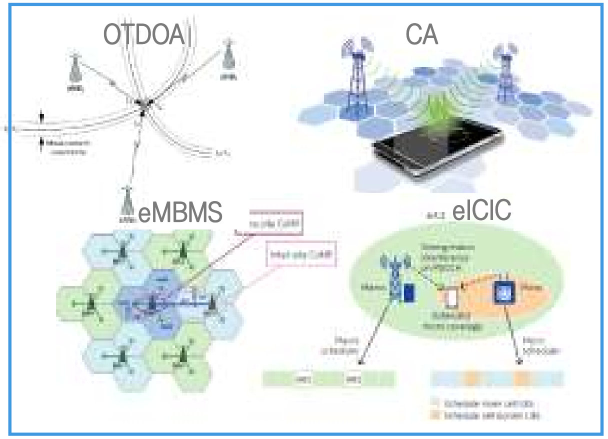
LTE-TDD / 5G NR-TDD



Interferencia problémák kezelése

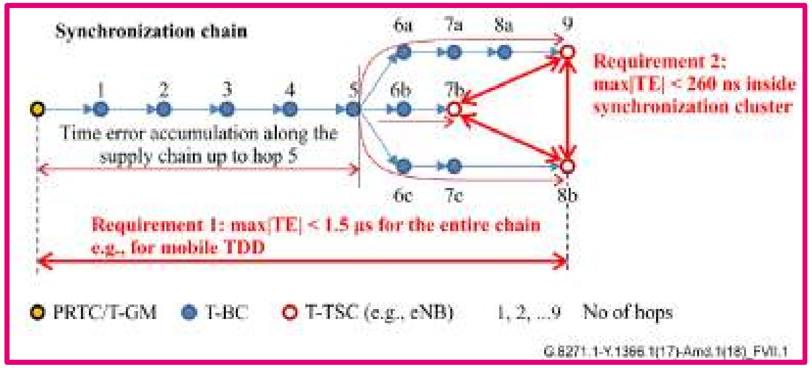


On-The-Top szolgáltatások



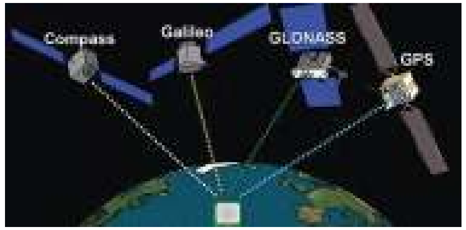
Sync specifikáció (ITU-T G.8271):

- Frekvencia pontosság < 50ppb (10^{-9})
- Fázis pontosság:
  - ➢ TDD alkalmazás (pontossági szint 4): TE < 1,5 µs (E2E)
  - ➢ Carrier Aggregation (pontossági szint 6A): TE < 260 ns (rel)



NR-TDD: New Radio Time Division Duplex
eMBMS: Multimedia Broadcast Multicast Services
OTDOA: Observed Time Difference Of Arrival
eICIC: enhanced Inter-Cell Interference Coordination
CA: Carrier Aggregation
TE: Time Error
CoMP: Coordinated MultiPoint

GNSS VAGY HÁLÓZATI SZINKRONJEL ELOSZTÁS

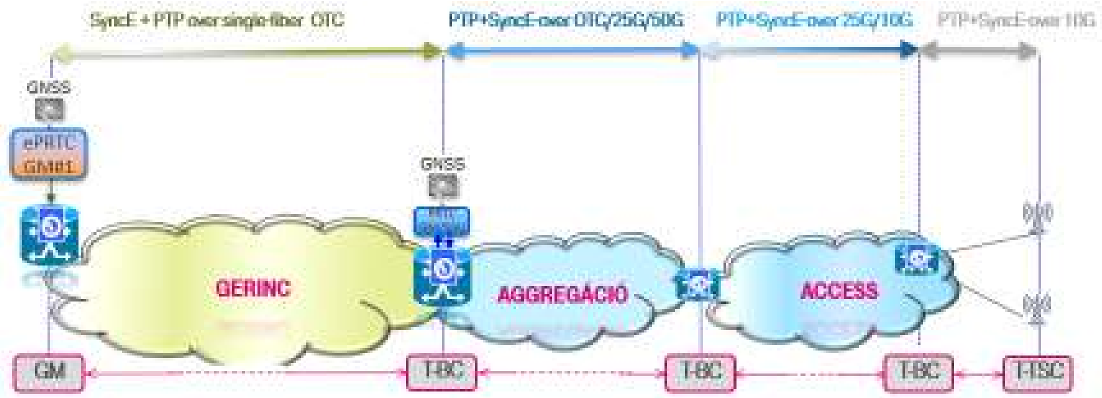


GNSS vevő alkalmazása a bázis állomásokon

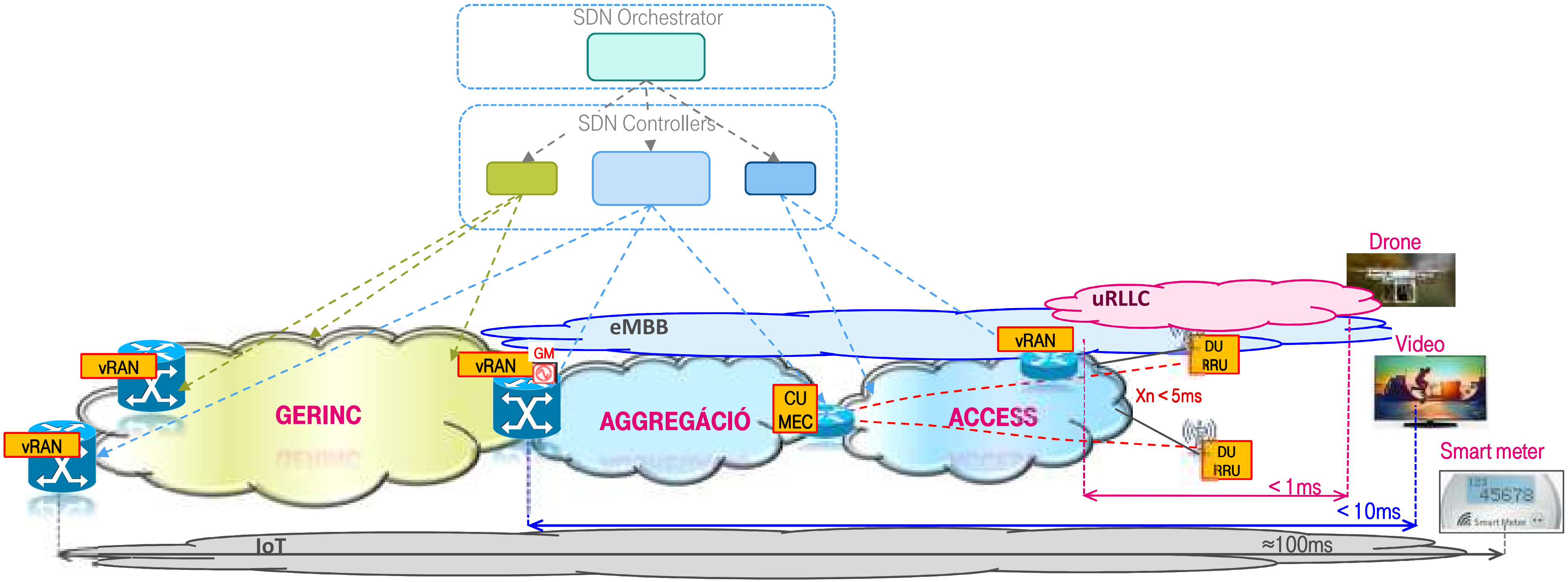
- Kézenfekvő megoldás a bázisállomások kiépítése GNSS vevőkkel, de problémát okozhat
  - A GNSS jelek sérülékenysége, zavarérzékenysége (légköri problémák, szándékosság)
  - A GNSS antennák elhelyezése beltéri alkalmazásoknál (bevásárló központok, irodaházak) és magas épületek határolta területeken (pl. urban canyon).
- Tartalék szinkronjel nélkül a bázis állomások üzemeltetése kockázatos

Szinkronjel elosztó hálózat alkalmazása – Pontosság, stabilitás, megbízhatóság

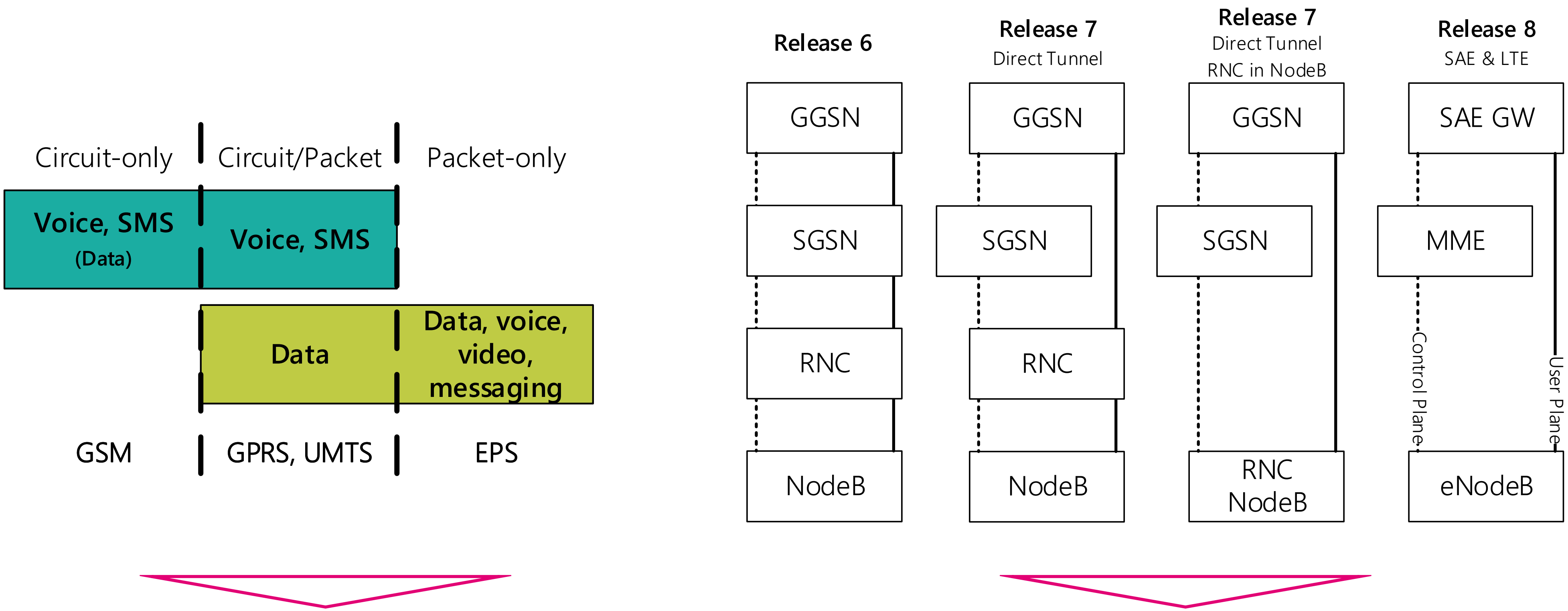
- GNSS alapú nagy pontosságú és stabilitású (Cesium alapú) szinkronjel forrás (ePRTC) alkalmazása
- Szinkronjel elosztó hálózat képes
  - A szinkronjel eljuttatására a bázisállomásokhoz kis jeltorzítással
  - GNSS jel kimaradás esetén a megfelelő minőségű szinkronjel biztosítására hosszabb ideig
- Frekvencia szinkronjel (SyncE) nagy stabilitást biztosít



SZOLGÁLTATÁS-ALAPÚ HÁLÓZAT SZELETELÉS
NETWORK SLICING



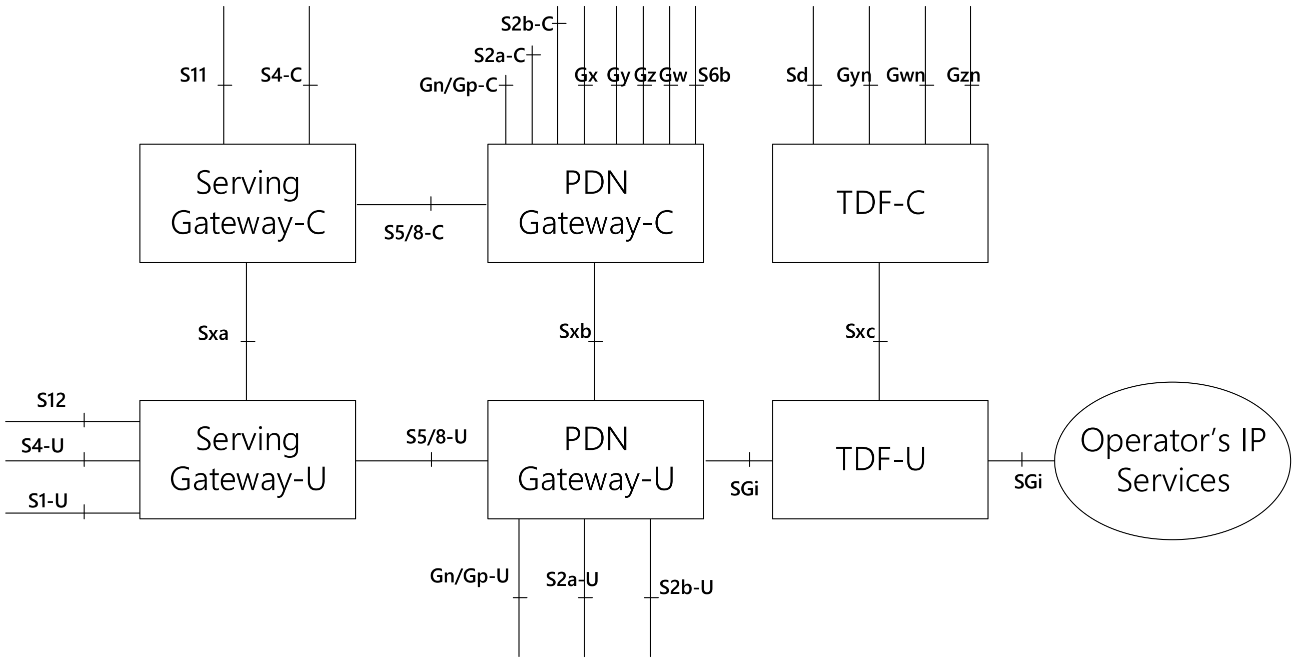
SYSTEM ARCHITECTURE EVOLUTION



Overall simplification, flat architecture

Források:
https://www.3gpp.org/technologies/keywords-acronyms/106-sae
https://www.3gpp.org/technologies/keywords-acronyms/100-the-evolved-packet-core

CONTROL AND USER PLANE SEPARATION OF EPC NODES (CUPS)



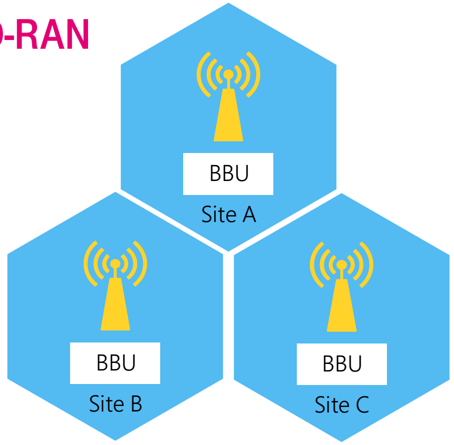
Architecture introduced in Release 14

- Reduce latency on application services
- Supporting increase of Data Traffic (distributed user plane nodes)
- Locating and scaling CP and UP resources of the EPC independently
- Independent Evolution of CP and UP functions
- Enabling SDN to deliver User Plane data more efficiently (network slicing?)

Forrás:
https://www.3gpp.org/cups

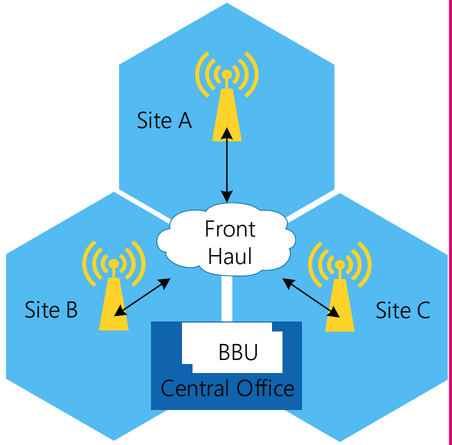
CLOUD-RAN CONCEPT

Traditional D-RAN



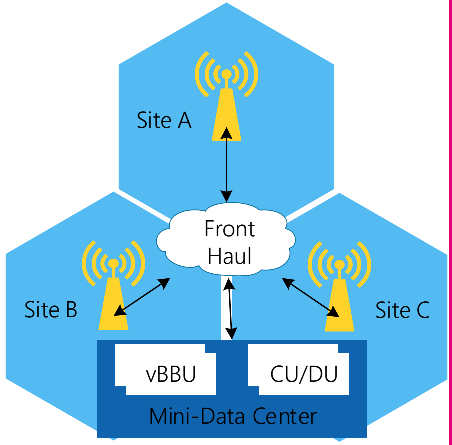
- Co-located BBU/RRU
- Dedicated BBUs
- Challenging for CoMP

C-RAN



- Centralized baseband units with potential for pooled baseband
- CPRI interconnect
- Enables CoMP and other LTE-A features
- Not virtualized

Cloud-RAN

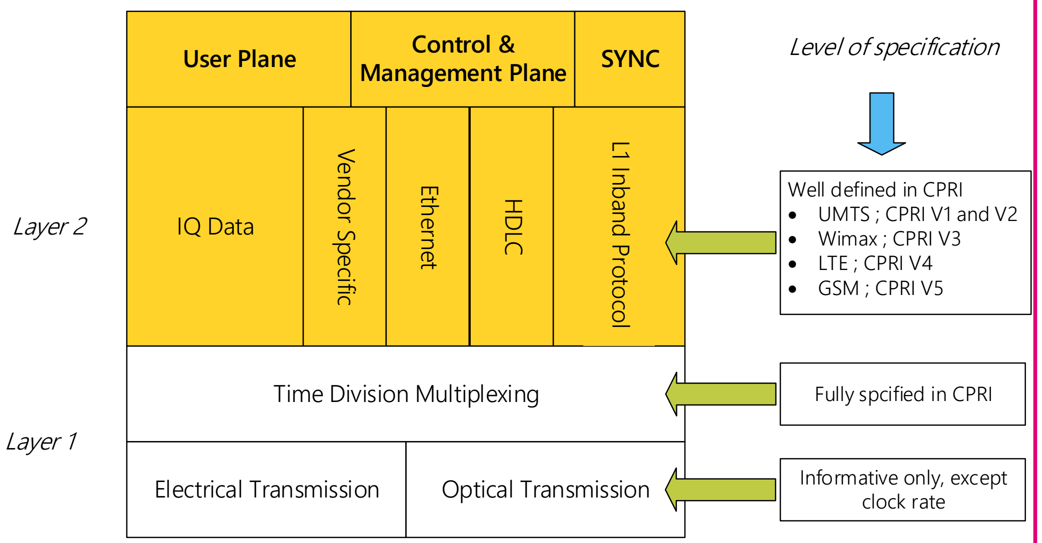


- Virtualized baseband
- CPRI, eCPRI, IEEE 1914.3 (Radio over Ethernet)
- New functional split CU/DU/RU (8 split options?!)

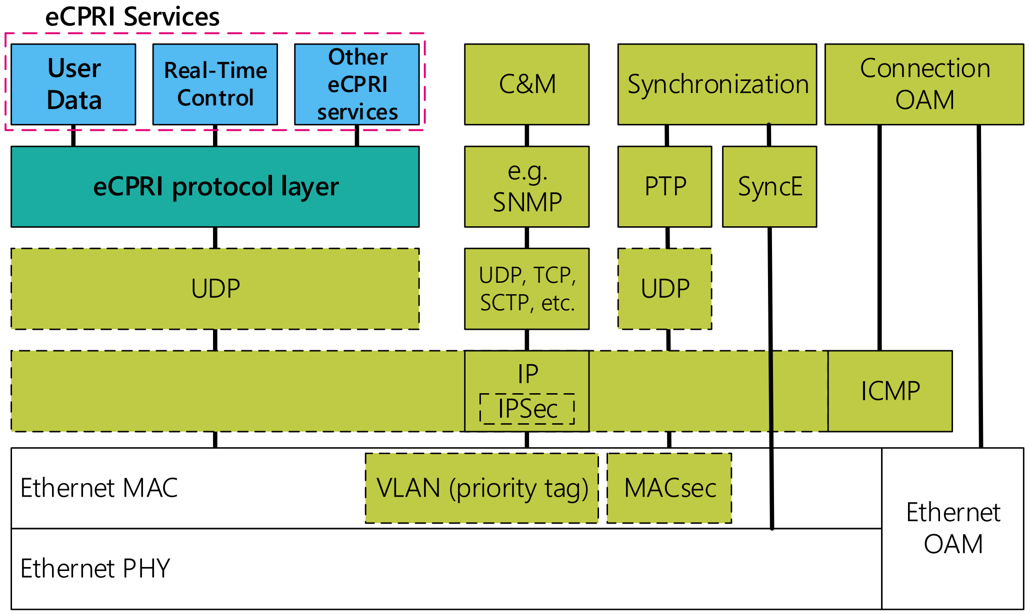
Forrás:
Cisco Live! 2019 BRKSPG-2402: The SP Service Edge Transformation

ENHANCED RADIO PROTOCOL STACKS

CPRI protocol stack

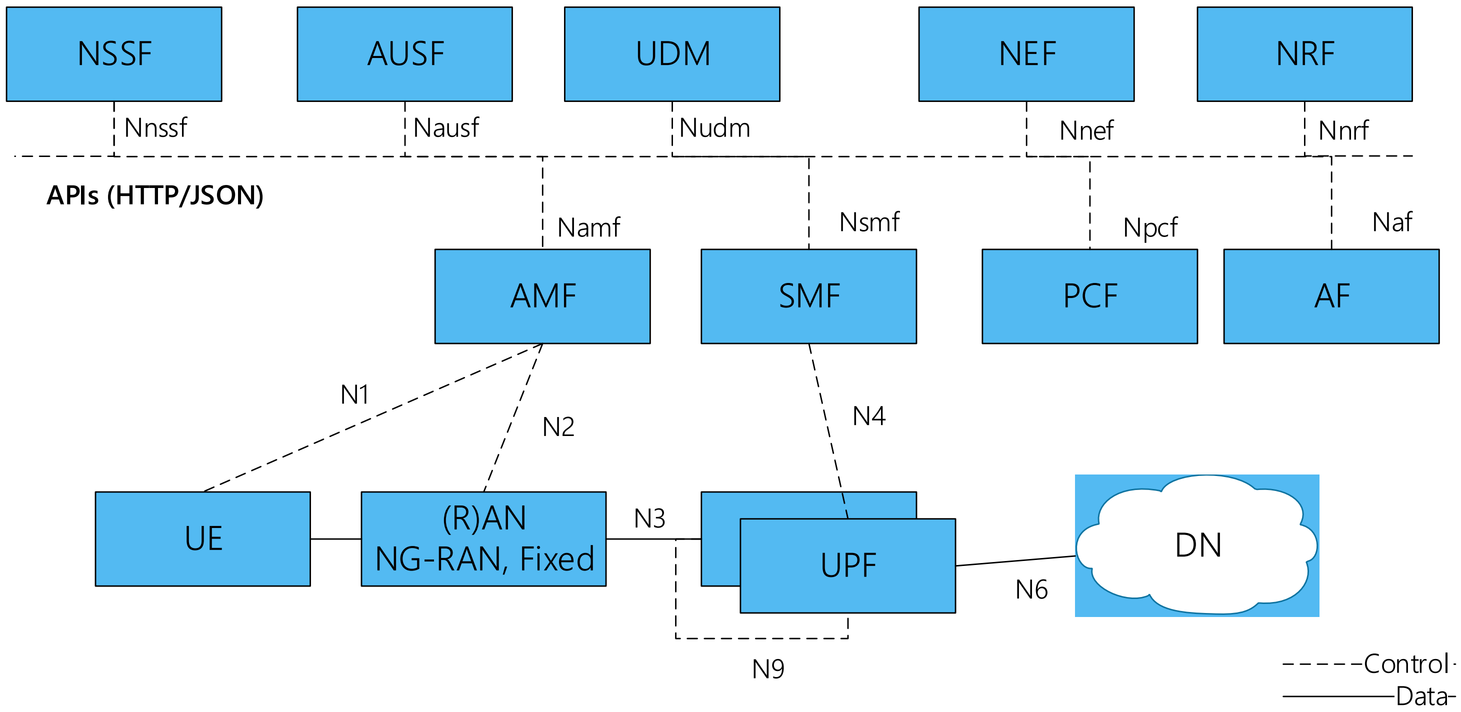


eCPRI protocol stack over IP/Ethernet



Forrás:
http://www.cpri.info/downloads/eCPRI_Presentation_for_CPRI_Server_2018_01_03.pdf

5G SA ARCHITECTURE

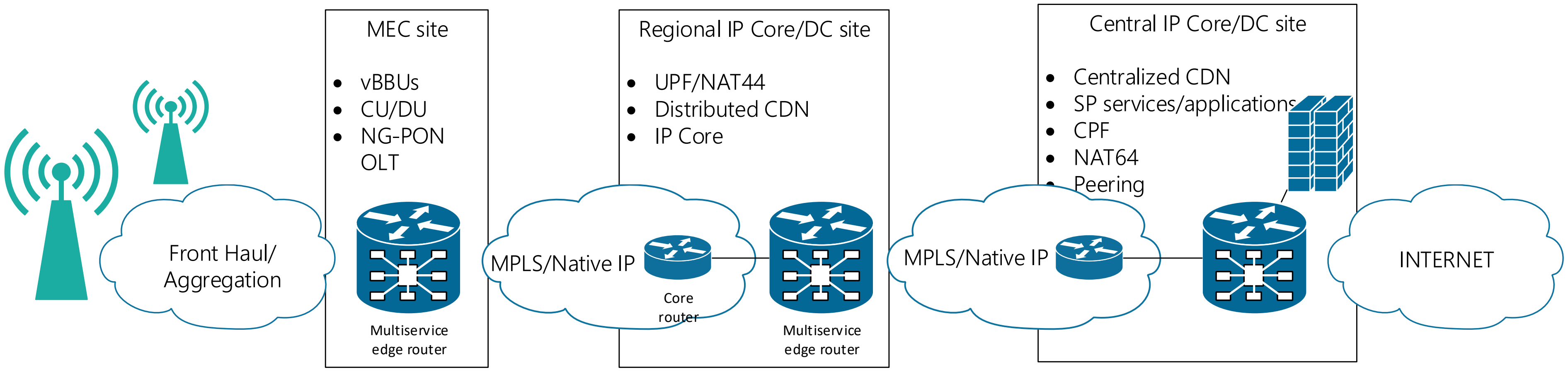


AUSF	Authentication Server Function
AMF	Access and Mobility Management Function
AF	Application Function
DN	Data Networks
SMF	Session Management Function

NEF	Network ExposureFunction
NSSF	Network Slice Selection Function
NRF	Network Repository Function
PCF	Policy Control Function
UPF	User Plane Function
(R)AN	(Radio) Access Network

Forrás:
https://www.cisco.com/c/dam/en/us/products/collateral/routers/network-convergence-system-500-series-routers/white-paper-c11-740360.pdf

ARCHITECTURAL CHANGES IN IP NETWORKING INFRASTRUCTURE



VNFS
WHITEBOX NETWORKING DEVICES

HIGH CAPACITY
Nx25/50/100G connections
Silo Cloud solutions

SDN & ELASTICITY
High port density
Elastic applications
Fully automated environments

SEGMENT ROUTING – SEAMLESS TRANSITION TO SDN?

Source based routing revolution

- Source chooses a path
- The chosen path is encoded in the packet header
- Ordered list of segments
- Segment IDs: prefix SID, adjacency SID

Segments: identifiers of instruction types

- Instructions:
  - Go to node N using the shortest path
  - Go to node N over the shortest path to node M and then follow links layer1, layer2 and layer3
  - Apply service S

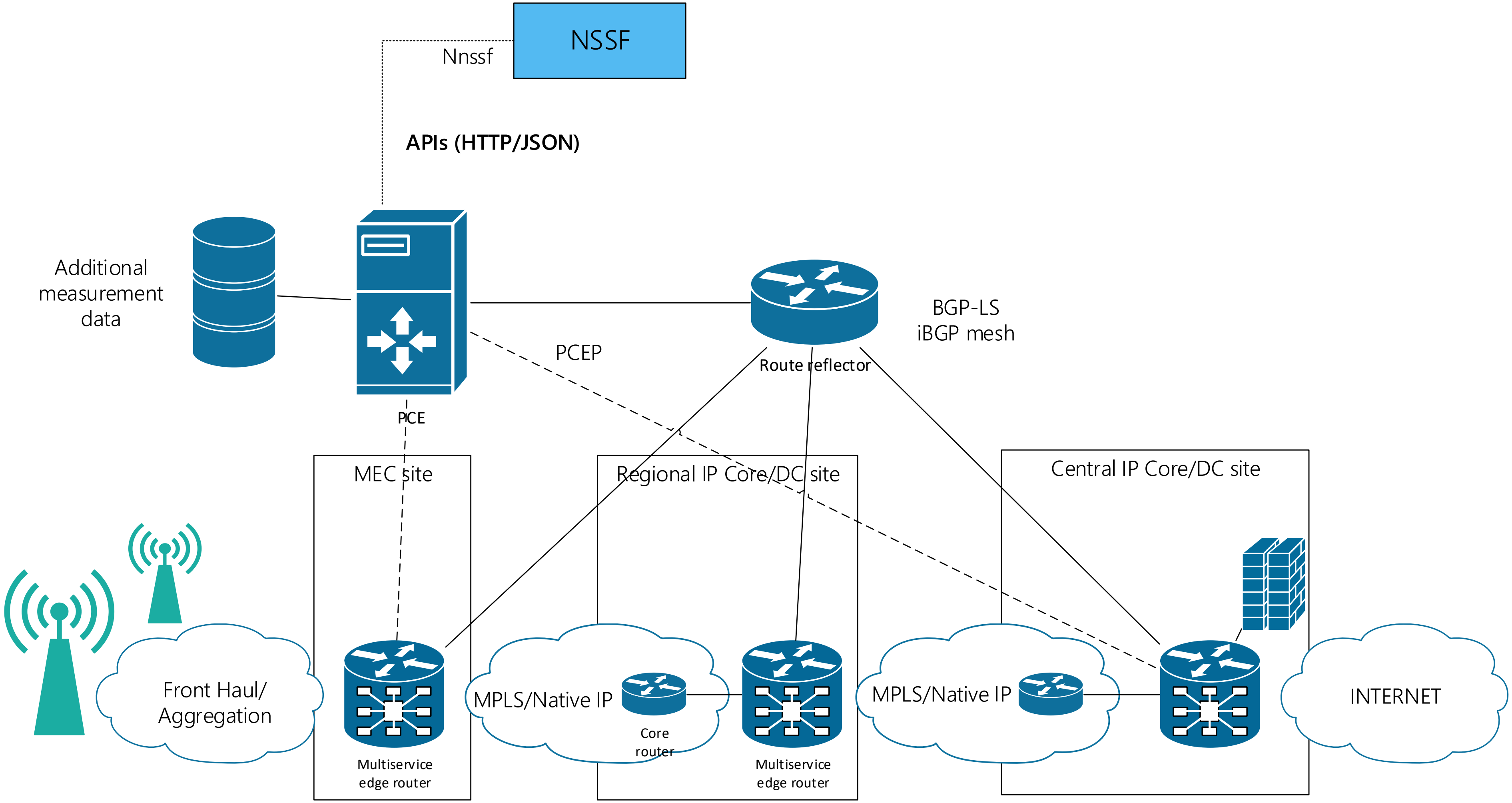
Minor IGP extensions

- IS-IS, OSPF IGP extensions
- Operates with MPLS and IPv6 data plane
- Integrates:
  - Layer3 VPN
  - Virtual Private Wire Service (VPWS)
  - Virtual Private LAN service (VPLS)
  - Ethernet VPN (EVPN)

ONLY IGP IS NEEDED

No other protocols required to distribute any SR information (eg.: LDP)

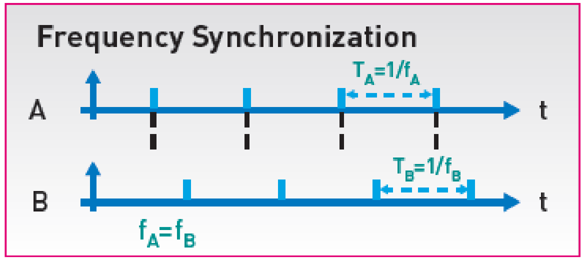
READY FOR SDN – THEORETICAL 5G SA EXAMPLE



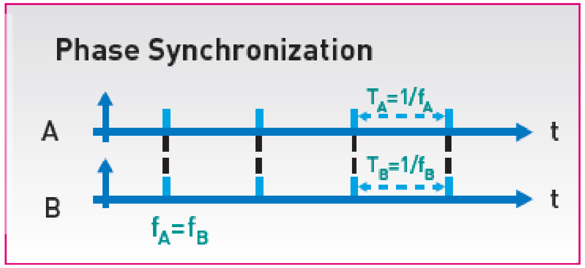
BACKUP

IDŐ/FÁZIS/FREKVENCIA SZINKRONIZÁLÁS

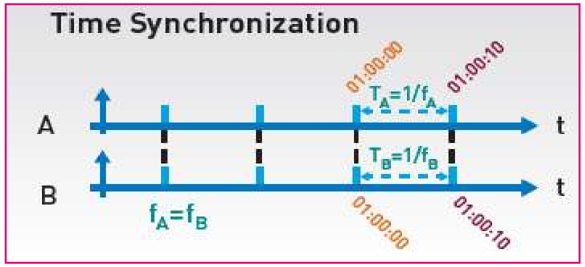
Az A és B impulzusok azonos ütemben követik egymást, de nem ugyanabban a pillanatban

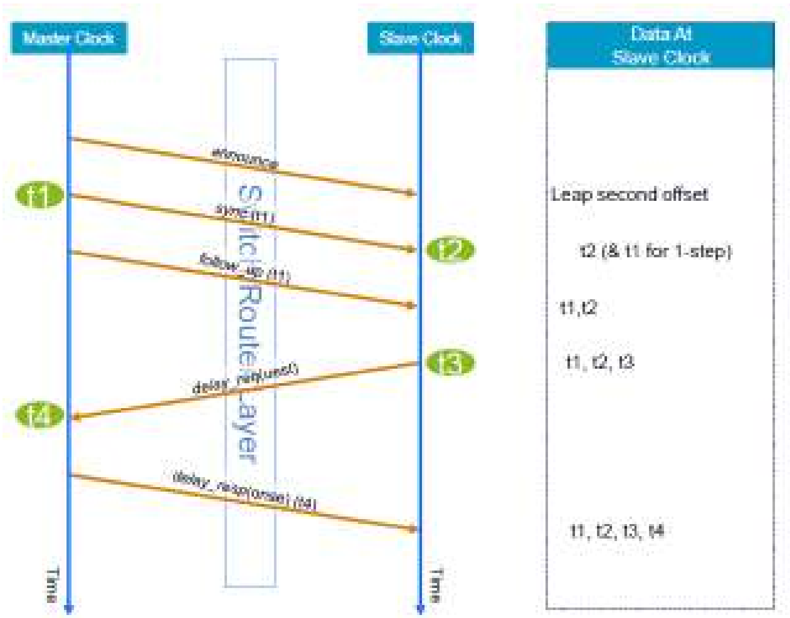


Az A és B impulzusok ugyanabban a pillanatban követik egymást



Az A és B impulzusok ugyanabban a pillanatban és azonos időben követik egymást





Slave Clock Error

Offset= (t2 - t1) - (RTD ÷ 2)= [(t2 - t1) –(t4 - t3)]/2

RTD= t2 – t1 + t4 – t3

PÉLDÁK A GNSS ZAVAROKRA

story 4 June 2018

GNSS Jamming and Spoofi
Hazard or Hype?

https://www.space-of-innovation.com/gnss-jamming-and-spoofing-hazard-or-hype/?PageSpeed=noscript

http://www.spacesafetymagazine.com/magazine/gnss-and-its-vulnerability/

JULY 24, 2017

Reports of Mass GPS Spoofing Attack in the Black Sea Strengthen Calls for PNT Backup

After reports of an apparent mass and blatant GPS spoofing attack involving more than 20 vessels in the Black Sea last month, navigatio experts and maritime executives are scratching their heads and the

https://insidegnss.com/reports-of-mass-gps-spoofing-attack-in-the-black-sea-strengthen-calls-for-pnt-backup/

JANUARY 29, 2016

GPS Glitch Caused Outages, Fueled Arguments for Backup

Less than a month after Europe switched off most of its Loran transmitters, a problem with GPS satellite timing signal triggered alarm across the continent and caused an unknown number of outages, including the disruption of some features of critical infrastructure.

https://insidegnss.com/gps-glitch-caused-outages-fueled-arguments-for-backup/

PÉLDÁK A GNSS ZAVAROKRA

Event Summary Table

	Network Type	Region	Qty GPS Elements	Notes
Customer A	Fixed Line	UK	Large	[illegible]
Customer B	Transport Carrier	UK	Small	[illegible]
Customer C	Fixed Line	Global	Large	[illegible]
Customer D	Fixed Line	UK	Small	[illegible]
Customer E	Transport Carrier	UK	Small	[illegible]
Customer F	Mobile	UK	Medium	[illegible]
Customer G	Private Network	UK	Small	[illegible]
Customer H	Mobile	UK	Medium	[illegible]
Customer I	Fixed Line	Sweden	Medium	[illegible]
Customer J	Mobile	UK	Medium	[illegible]
Customer K	Mobile	UK	Medium	[illegible]

FEBRUARY 3, 2016

BBC, Chronos Report on Lengthy Disruptions Caused by GPS Timing Problem

The British Broadcasting Corporation (BBC) said yesterday (Februa… 2016) that the recent decommissioning of a GPS satellite led to difficulties for listeners receiving digital radio signals.

https://insidegnss.com/bbc-chronos-report-on-lengthy-disruptions-caused-by-gps-timing-problem/

https://hvg.hu/tudomany/20181112_nato_hadgyakorlat_finnorszag_norvegia_gps_jel_blokkolasa_muhold_tajekozodas

Russia suspected of jamming GPS sign… in Finland

12 November 2018

https://www.bbc.com/news/world-europe-46178940

Science & Environment

Map illustrates 'Russian GPS' failure

By Jonathan Amos
Science correspondent, BBC News

9 April 2014

https://www.bbc.com/news/science-environment-26957569

APRIL 16, 2014

GLONASS Fails Again, Briefly

Russia's GLONASS satellite navigation system reportedly suffered another major disruption on Tuesday (April 15, 2014), with eight satellite… malfunctioning and another going off the air entirely.

https://insidegnss.com/glonass-fails-again-briefly/