

# Non-Terrestrial Disaggregated RAN: Prospective Architectures and Performance Insights

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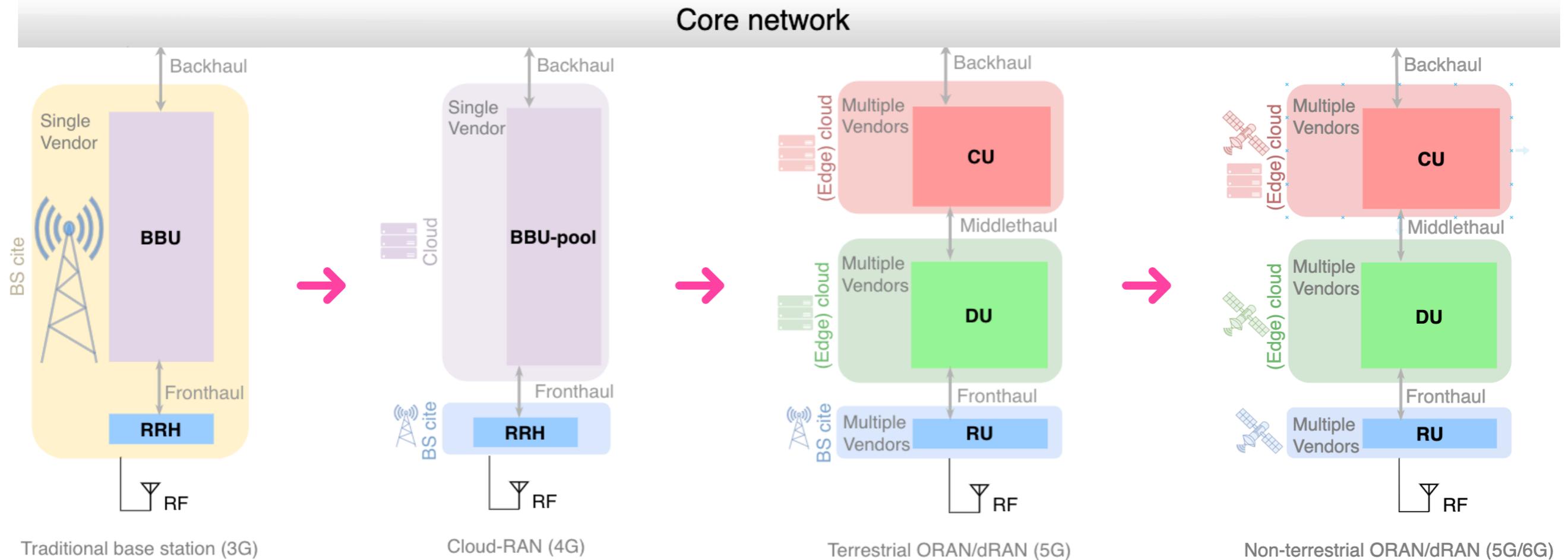
NTN Days 2024

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# Radio Access Network (RAN) Evolution in Mobile Networks



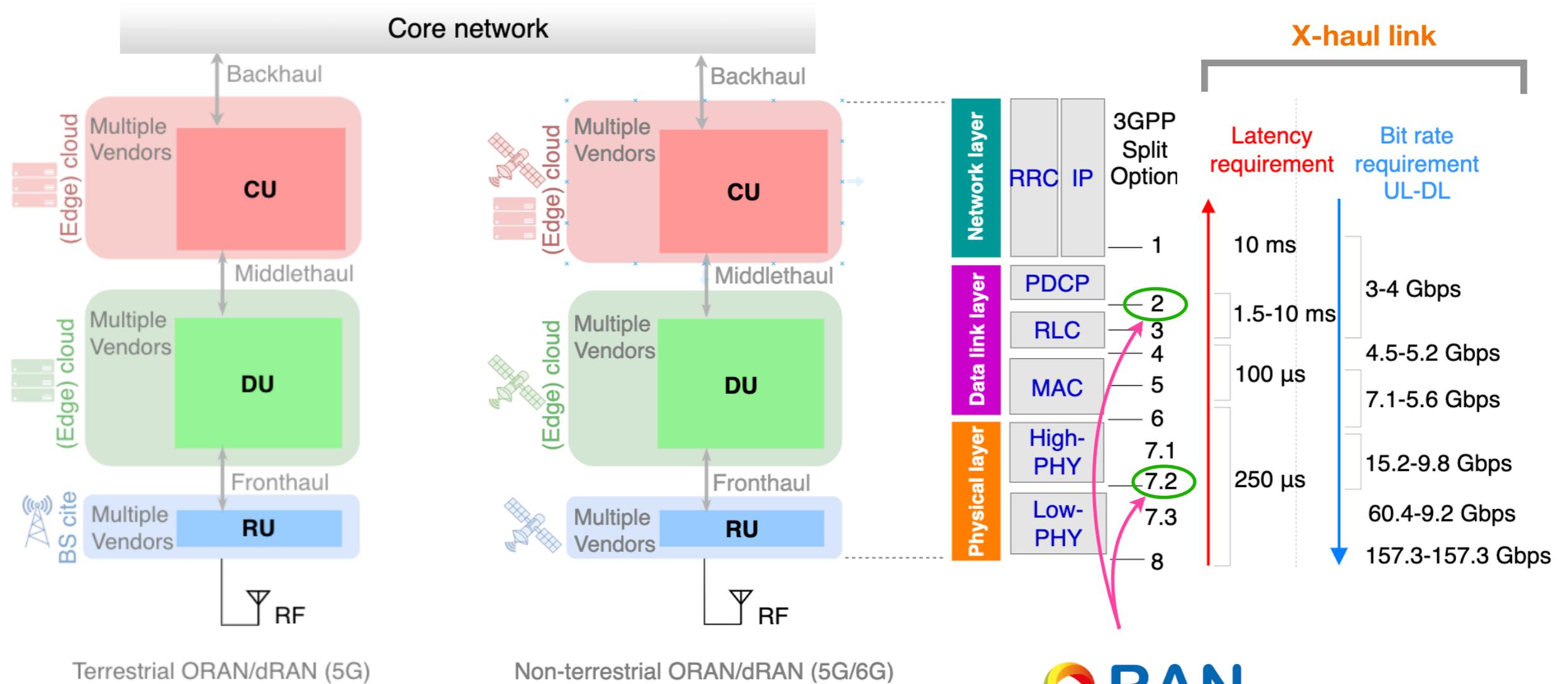
Monolithic,  
single-vendor,  
closed system

Centralized  
processing,  
efficient resource  
pooling

Disaggregated,  
multi-vendor,  
flexible architecture

Extended to  
satellites, global  
connectivity

# Functional Split Options & X-haul link Requirements

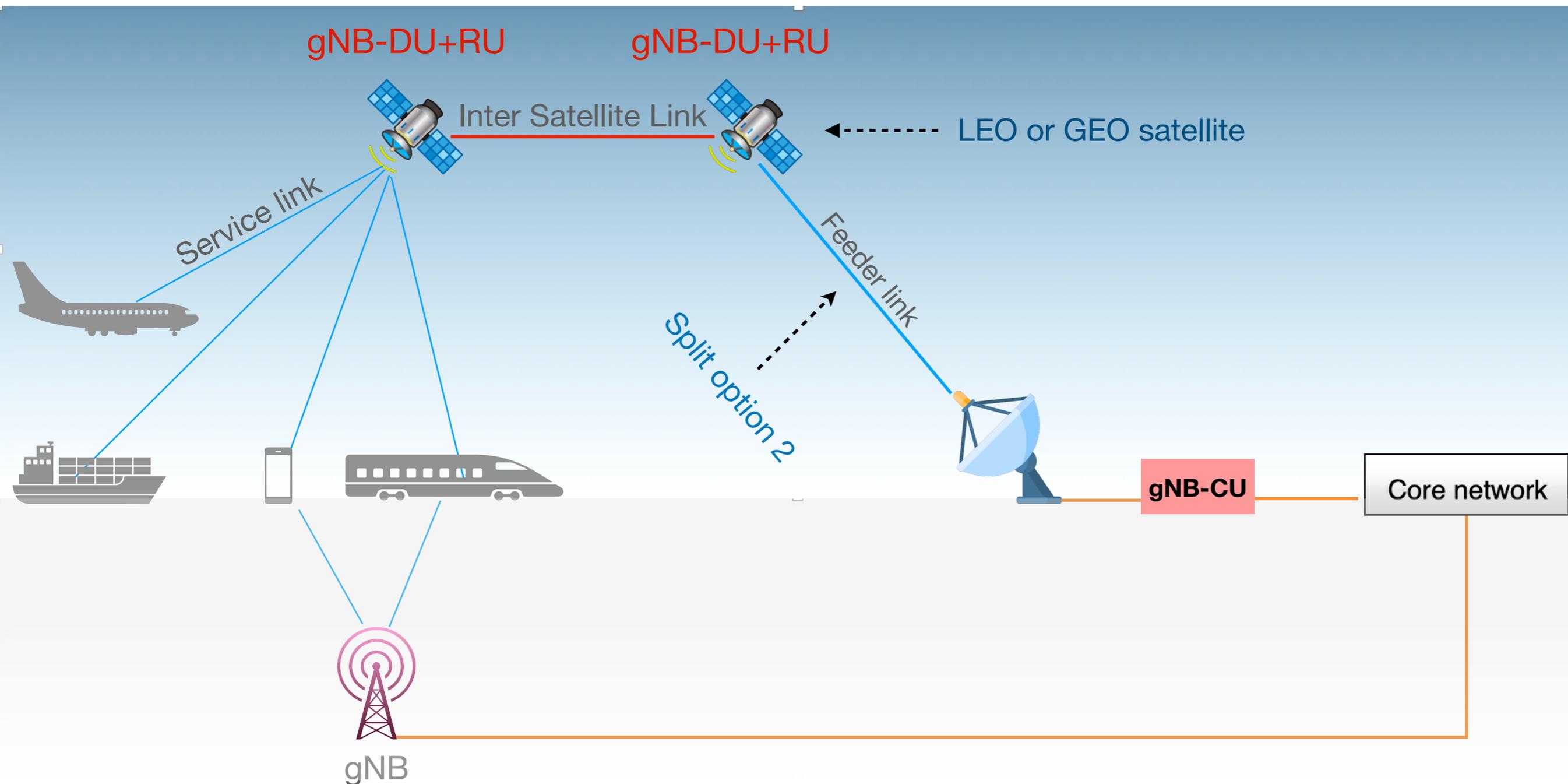


X-haul means all Frontahaul, Middlehaul, and Backhaul links



# Non-Terrestrial Networks disaggregated RAN: 3GPP proposition

- Ground-based gNB-CU
- Integrated DU and RU onboard
- Multi-connectivity for continuous service



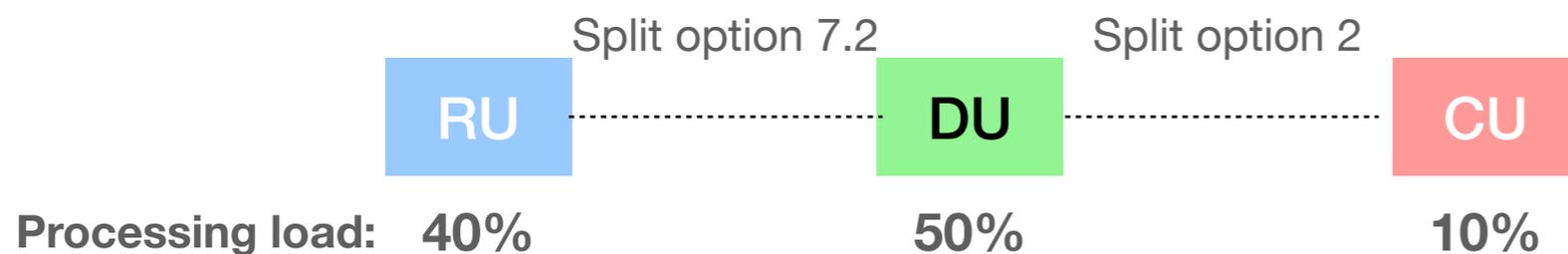
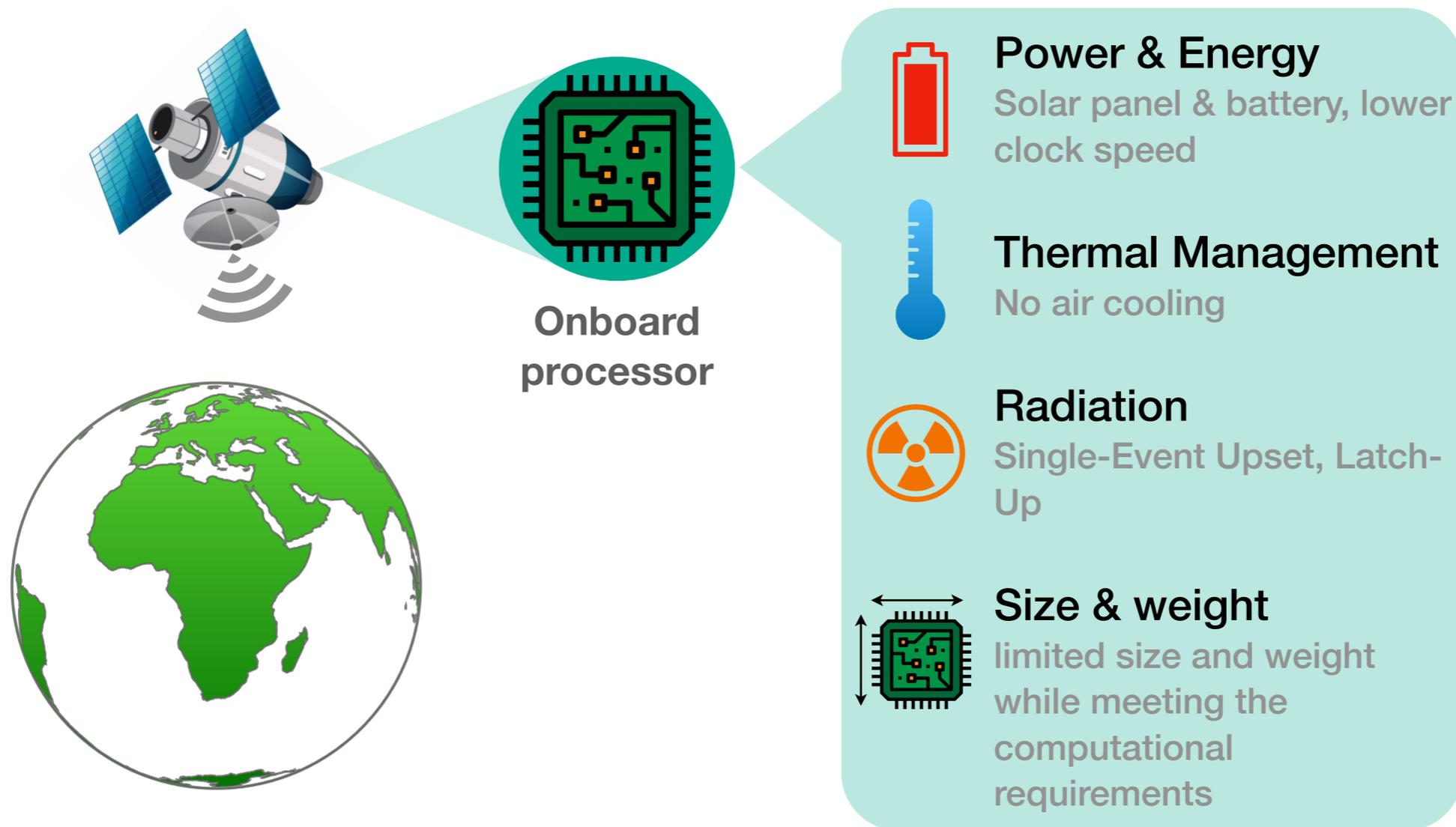


## **Our objectives:**

- **What are the challenges in non-terrestrial dRAN?**
- **Can we expand non-terrestrial dRAN beyond 3GPP for better efficiency?**

# Open Challenges in Non-Terrestrial dRAN:

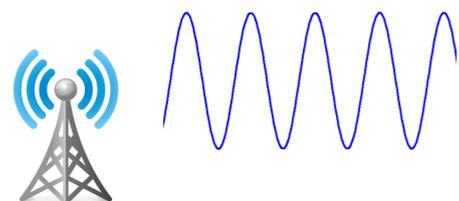
## # Limited onboard satellite computing



- Integrated DU+RU = 90 %
- Altering the split options can offload processing to the CU

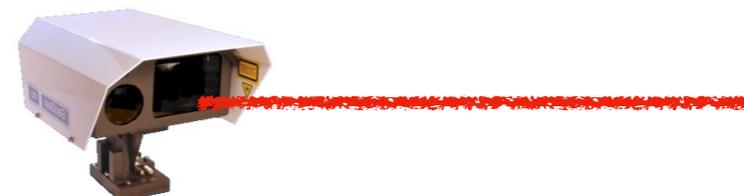
# Open Challenges in Non-Terrestrial dRAN:

## # X-haul link technologies & bitrate



### Radio Frequency (RF) links:

- 300 MHz - 300 GHz
- Licensed
- High rain attenuation at high frequencies

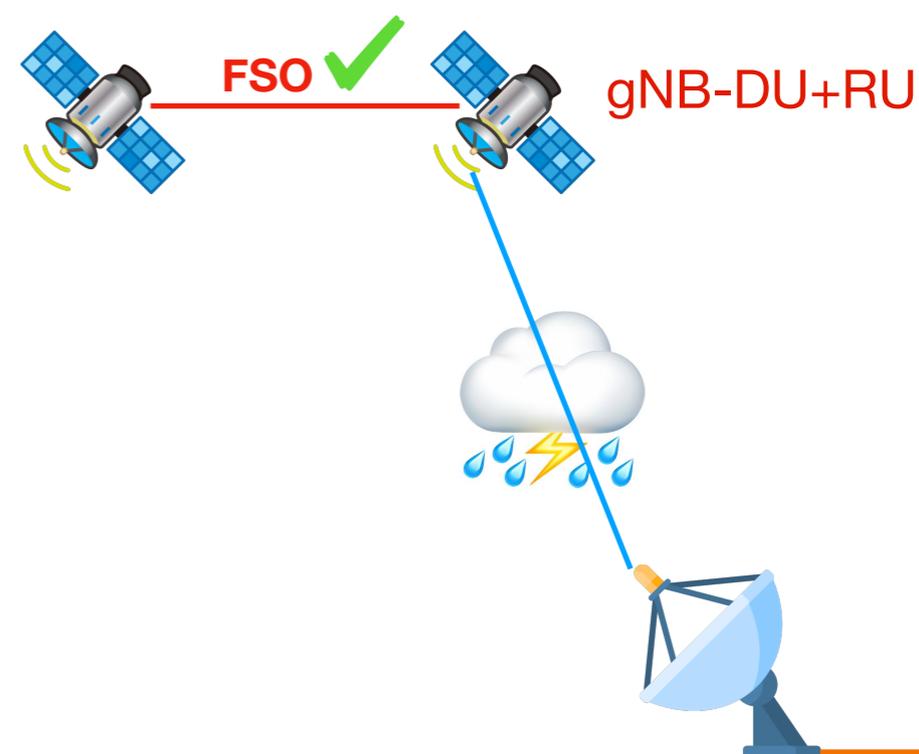


### Free Space Optical (FSO) links (Line-of-sight):

- High bandwidth ( 20-375 THz, unlicensed)
- High attenuation in fog, haze, dust

Atmospheric turbulence may reduce space-ground link availability and reliability, despite expectations of 99.999% availability

	FSO	RF
Availability	Dense fog: 0.51 %	Dense fog: 100 %
	Rain: 87.71 %	Rain: 14.29 %
	Snow: 39.49 %	Snow: 100 %



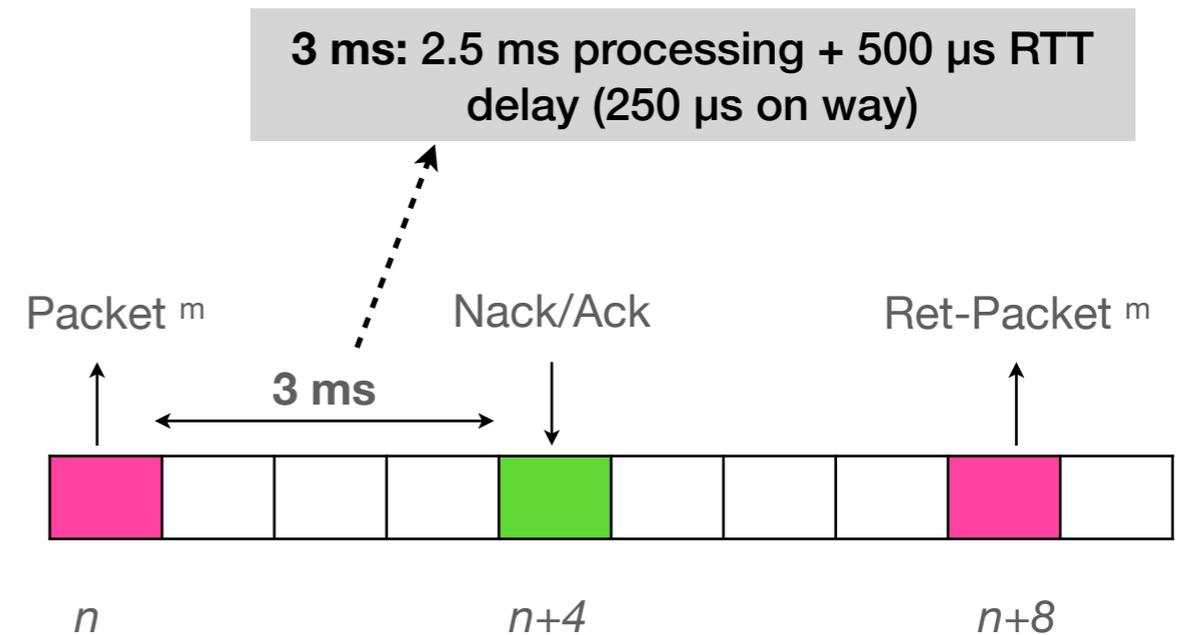
# Open Challenges in Non-Terrestrial dRAN:

## # X-haul Latency Requirements

- Split option latency limits X-haul distance (propagation latency)
- Why **250  $\mu$ s** for split option 7.2?

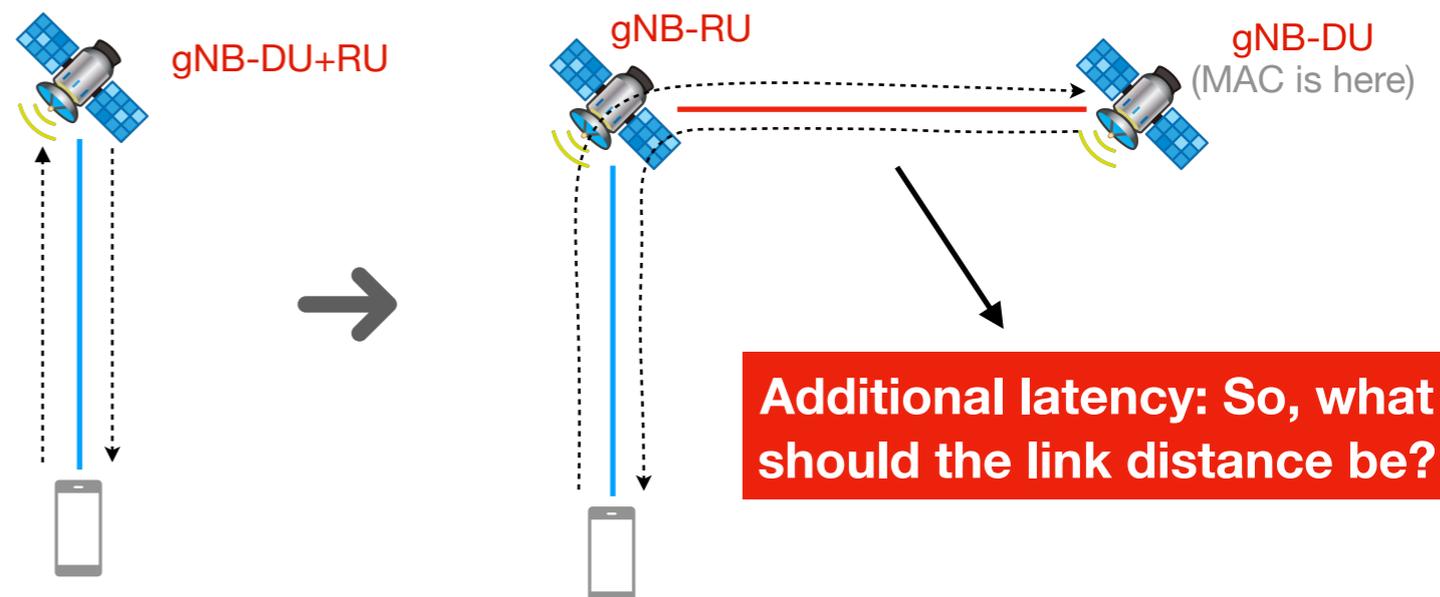
To adapt HARQ to NTN (3GPP):

- Disable HARQ
- Adapt it for long distances (e.g., 32 ms instead 3 ms)



HARQ (Hybrid Automatic Repeat Request) in 4G-LTE

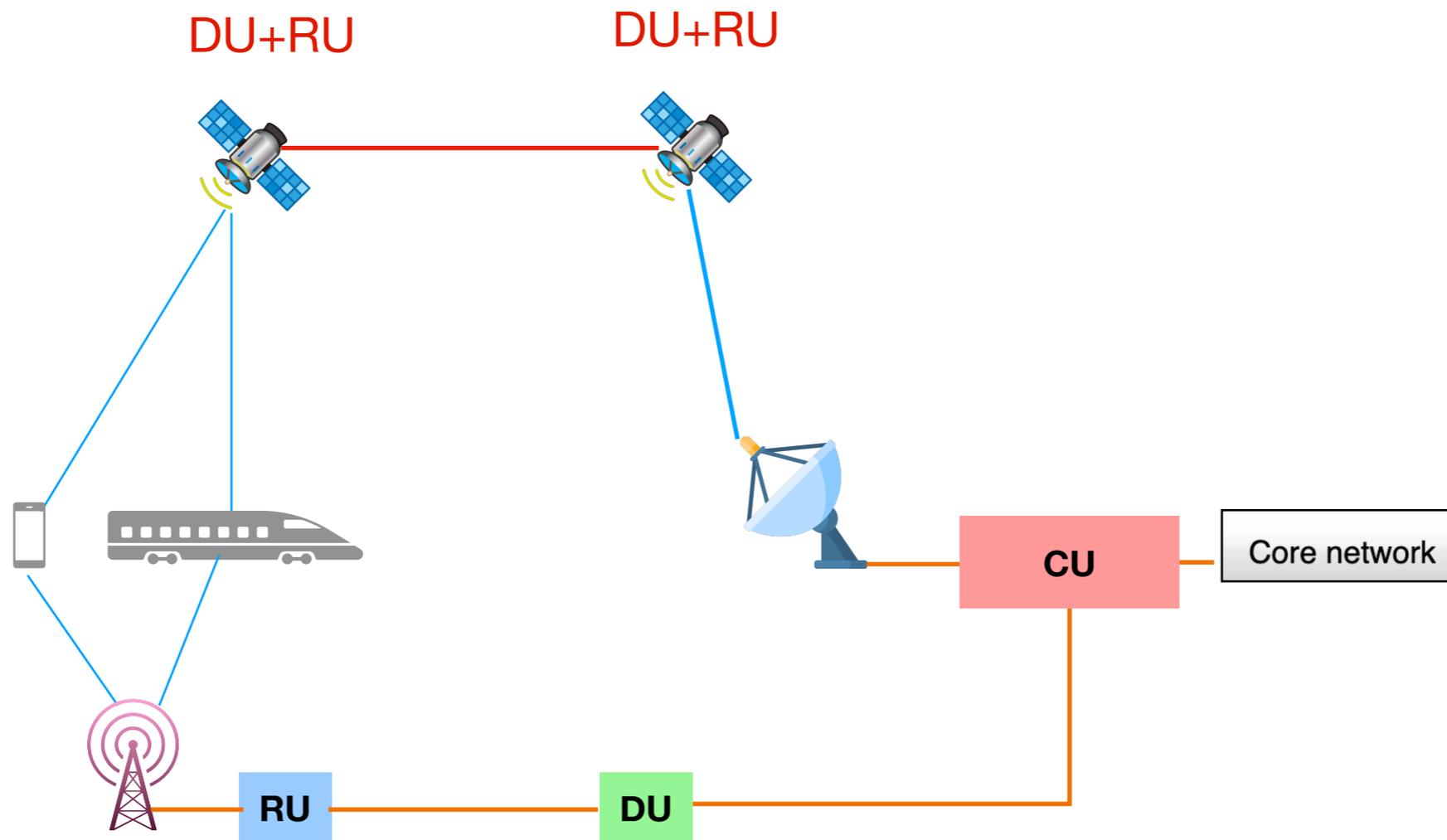
**What if we separate the DU and RU on different satellites?**



# Open Challenges in Non-Terrestrial dRAN:

## # Multi-connectivity Support

- Multi connectivity is needed for service Continuity
- How to adapt dRAN to multi connectivity?
  - One CU or multiple?
  - Where is the CU(s) located?

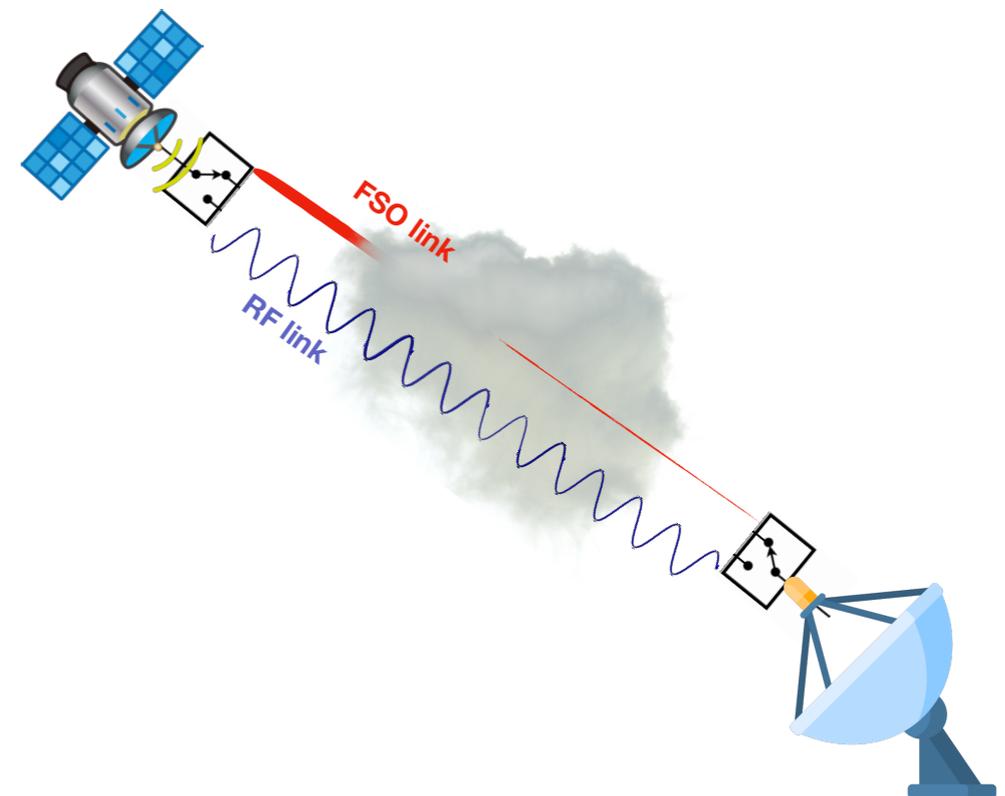


# Hybrid FSO/RF Links for Space-ground Communication

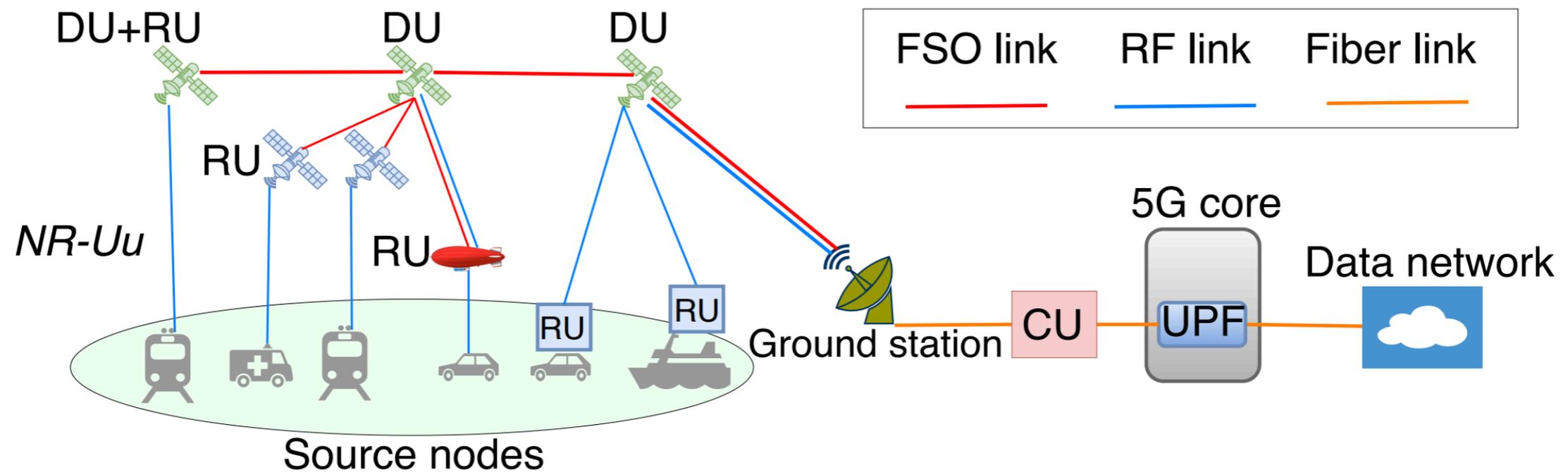
	FSO	RF	Hybrid FSO/RF
Availability	Dense fog: 0.51 %	Dense fog: 100 %	Dense fog: 100 %
	Rain: 87.71 %	Rain: 14.29 %	Rain: 87.71 %
	Snow: 39.49 %	Snow: 100 %	Snow: 100 %

FSO and RF links complement each other in varying atmospheric conditions

- Dynamic switch between FSO and RF (FSO primary link)
- Further enhanced reliability via **combining** and **coding**



# RU Placement Strategy



## RU+DU on single satellite

- No fronthaul latency
- High computational load
- Long user link

## RU on HAPs:

- Enhance user link budget
- Additional latency on fronthaul
- Short HAPs lifespan

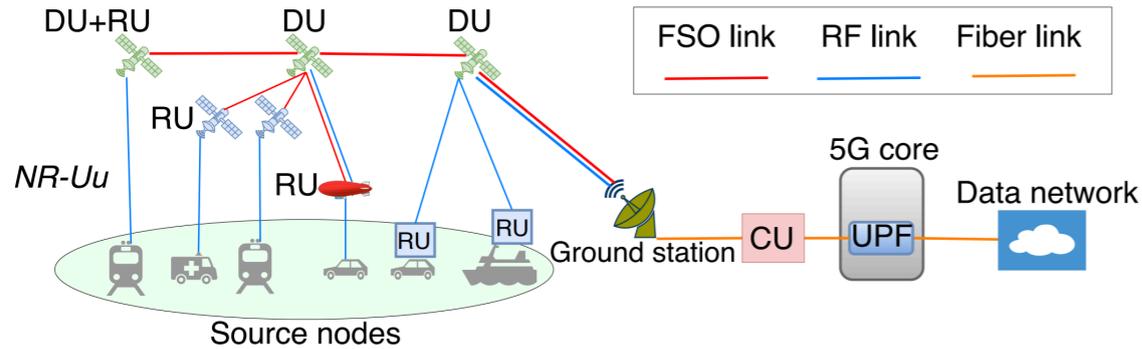
## RU on Distinct Satellite:

- Reduce computational load
- Place RU in lower orbit (help user link)
- One DU can manage several RUs
- Additional latency on fronthaul

## RU integrated with UE

- Efficient user link
- Difficult to use FSO (high mobility)
- Limited bitrate
- Limited applications

# Fronthaul Efficiency (RU-DU)



Parameter	Value
Satellite Altitude (LEO)	300 to 1500 km
Elevation Angle	10° to 90°
ISL Distance (Inspired by Starlink)	659 to 5400 km (US to Europe)
HAP Altitude	20 km
Distance between GS and 5G Core	Less than 200 km
RU-DU Distance (TNs)	Less than 20 km
DU-CU Distance	20 to 40 km
CU and GS Assumption	Colocated when CU is ground-based

Scenario	One-way FH availability (%)	One-way FH bit rate (Gbps)	One-way FH latency (ms)
RU integrated with UE access point	Unavailable in mmWave and heavy rain to 99.99 % in low GHz	up to 1+	1 to 12.5
RU on HAPs	more than 99	up to 400+ <sup>**</sup>	0.93 to 12
RU+DU on one satellite	100	Max Onboard data transfer	Negligible
RU on distinct satellite	more than 99 <sup>*</sup>	up to 400+ <sup>**</sup>	2.1 to 18

\* Based on commercial systems, e.g., Starlink and SpaceDataHighway

\*\* Based on ESA and NASA specifications

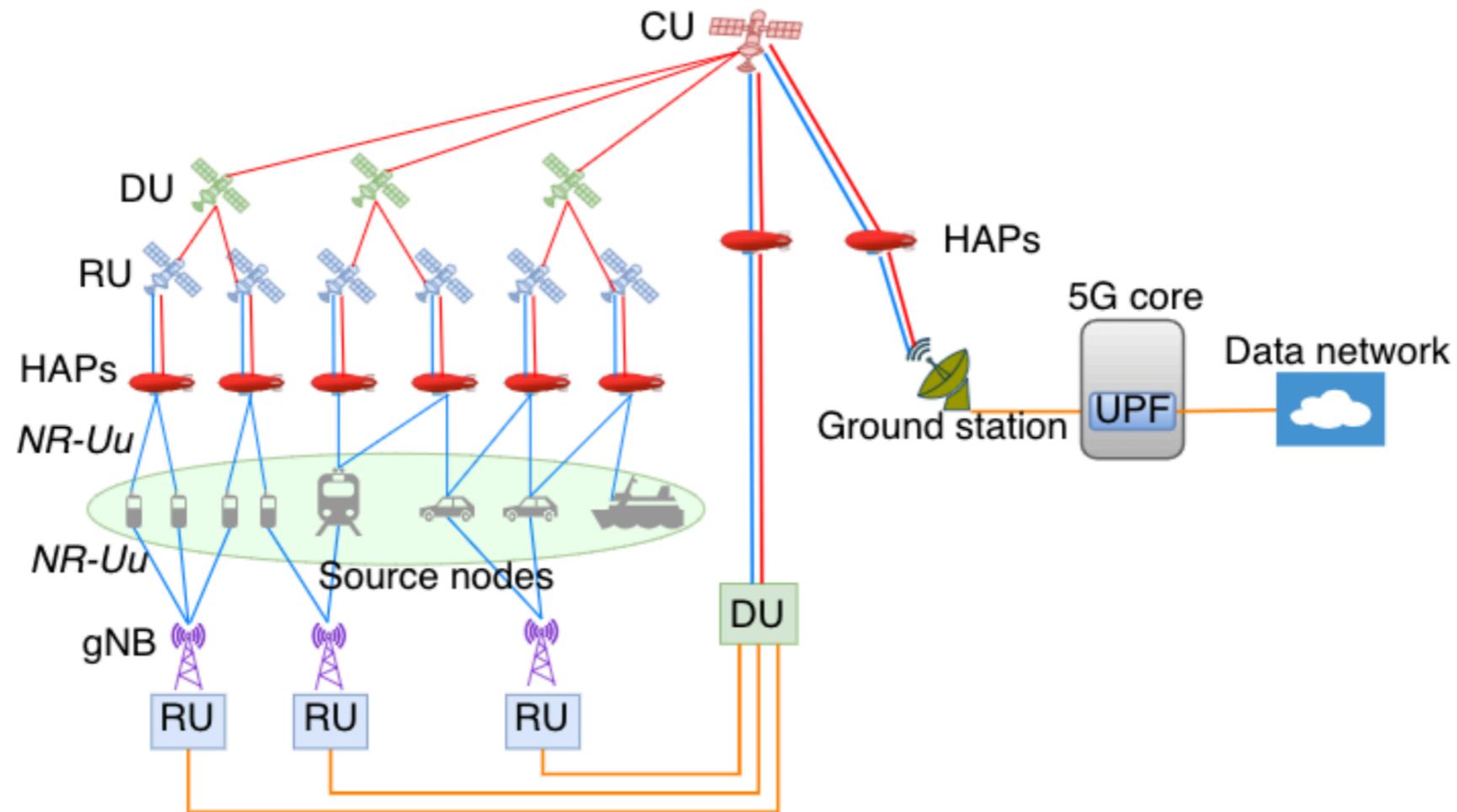
- RU on distinct satellites enables more functions.
- With relaxed NTN FH latency and FSO link capacity, split options from 7.2 and below are feasible for RU-DU FH connections.





# CU Placement Strategy

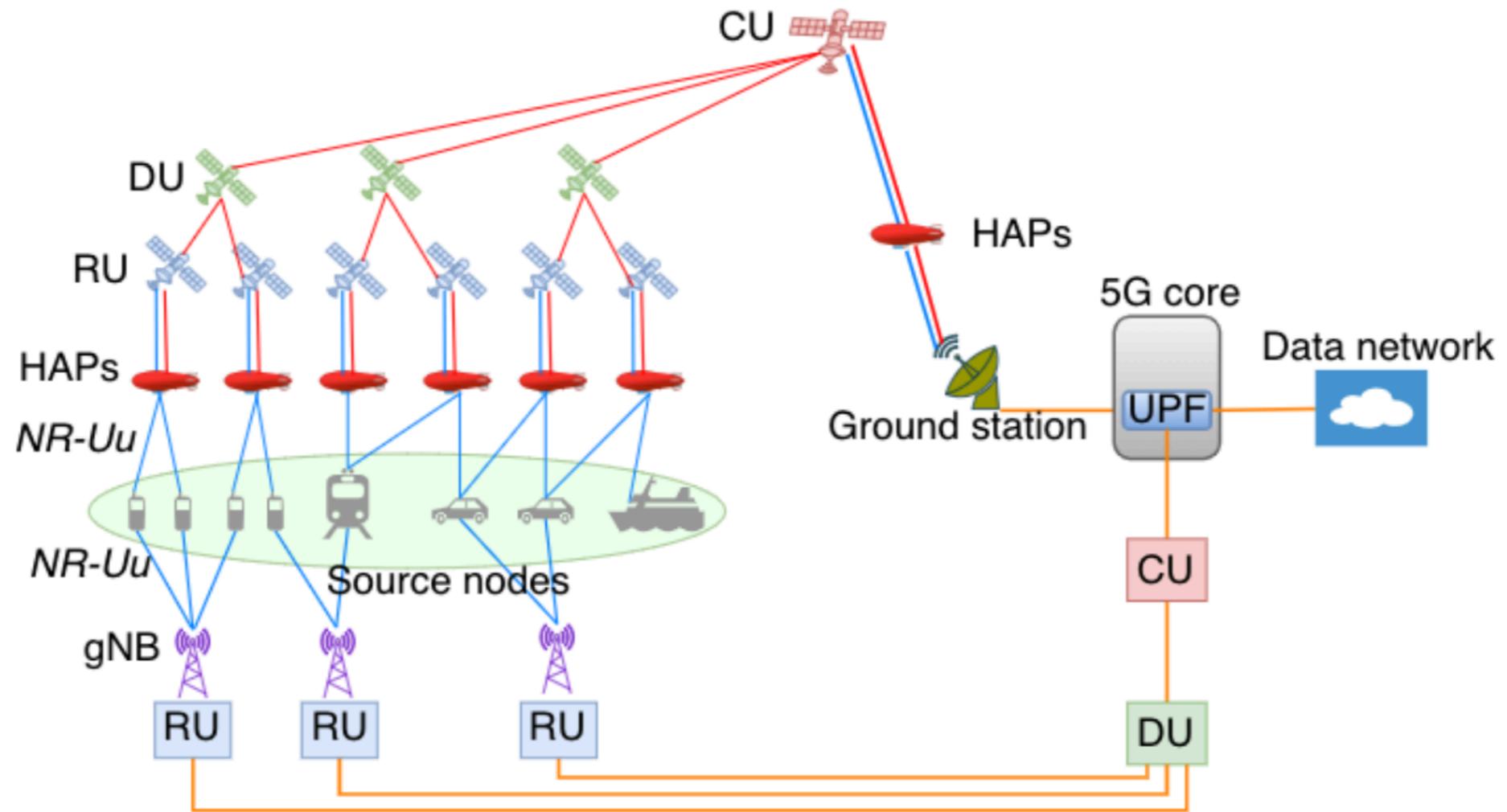
**Scenario C:** a single CU in space, assisted by HAPs, manages both terrestrial and non-terrestrial dRAN networks



- Non terrestrial network exploit the FSO link for fronthaul and middlehaul links
- Terrestrial network traffic is compromised two times space-ground links
- The appropriate functional split can be adjusted based on ISL delays between dRAN units in the NTN and the ground-space link in terrestrial dRAN.

# CU Placement Strategy

**Scenario D:** different CUs on the ground and in space manage terrestrial and non-terrestrial dRAN networks independently



- Core network manages UE traffic across different connectivity options

# X-haul Efficiency

Scenario	X-haul link availability (%)			X-haul link bit rate (Gbps)			X-haul link latency (ms)		
	NTN	TN	MC	NTN*	TN	MC	NTN	TN	MC
<b>A:</b> Single CU on the ground	85-99.16	99.7-99.97	99.95-99.999	≤ 200	≤ 600	≤ 600	5.3-26.19	0.11-27	0.11-27
<b>B:</b> Single CU on the ground + HAPs assisted	85-99.57	99.7-99.97	99.95-99.999	≤ 200	≤ 600	≤ 600	5.3-26.19	0.11-27	0.11-27
<b>C:</b> Single CU in space + HAPs assisted	85-99.57	74.78-99.54	96.21-99.998	≤ 200	≤ 600	≤ 600	5.3-26.19	2-29.1	2-29.1
<b>D:</b> CUs on the ground & in space	85-99.57	99.7-99.97	99.95-99.999	≤ 200	≤ 600	≤ 600	5.3-26.19	0.11-27	0.11-27

\* NASA achieved a 200 Gbps space-to-ground laser link, which acts as a bottleneck for end-to-end bit rates in NTN links

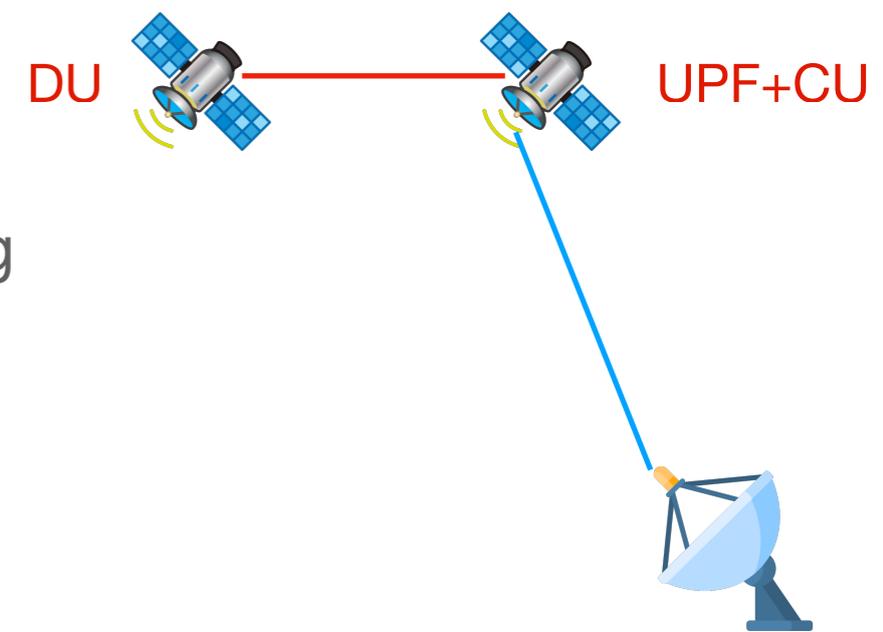
- B and D are the most efficient scenarios

## In scenario D:

- Lower-layer split options 3, 4, and 5 between DU and CU implement (HARQ located in DU)
- Split option 6 (DU-CU) → offload 20% more baseband processing to the CU, but placing HARQ at the CU better suits non-ideal applications

# Conclusion and Perspectives

- Deploying RU and DU on distinct satellites with FSO links enhances fronthaul efficiency
- Deployment CUs on both ground and space, managed by the 5G core, expand dRAN potential in NTN
- Placing the CU in space is also compatible with deploying parts of the core network on the satellite
- Future strategies should assess control plane expansions in NTN



**Thank you!**

