NTN days 2025

Increasing the throughput of Direct-to-Satellite Narrowband IoT networks

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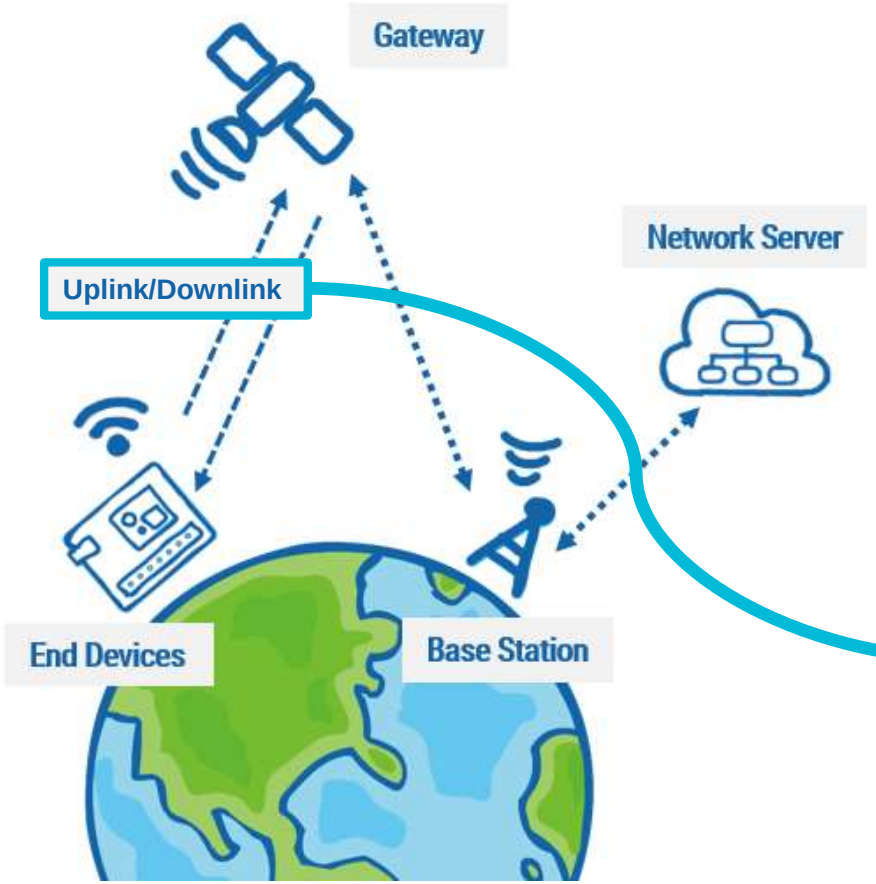
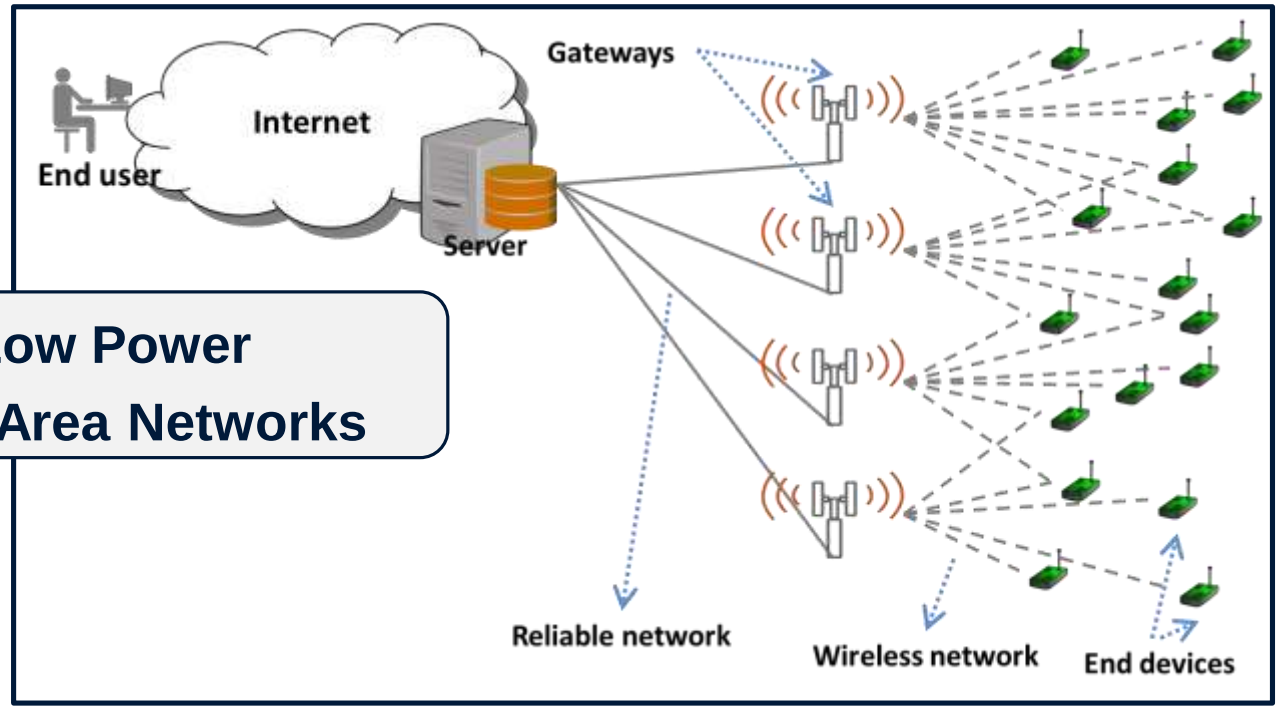
LPWAN for IoT-enabled LEO satellites





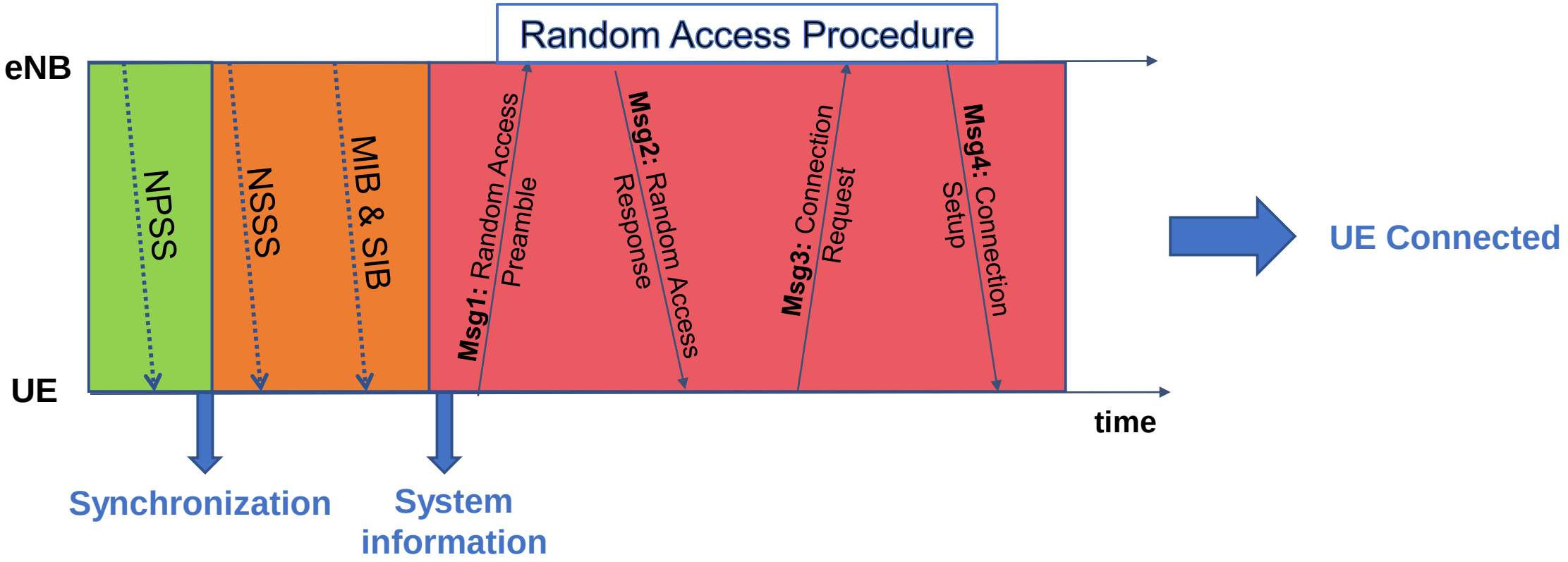
Low Power Wide Area Networks

Satellite protocols ⟷ IoT applications

Direct-to-Satellite protocols

Narrowband Internet of Things

NB-IoT



NPSS: Narrow Band Primay Synchronization Signal
NSSS: Narrowband Secondary Synchronization Signal
SIB: System Information Block
MIB: Master Information Block

UE: User Equipement
eNB: evolved Node B

Research Problems: Satellite NB-IoT without GNSS

Synchronization *[1]*

Doppler effect
Variable distance

↓

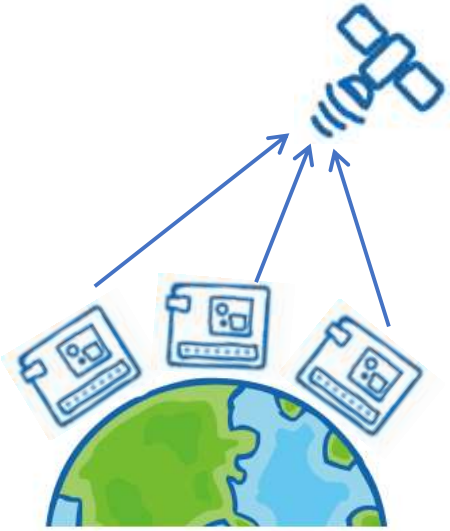
Frequency and Time Offset

Availability *[2]*

No satellite in range

↓

High energy consumption



High access demand

More collisions

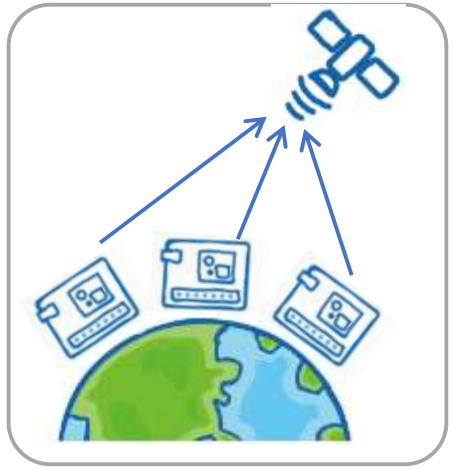
↓

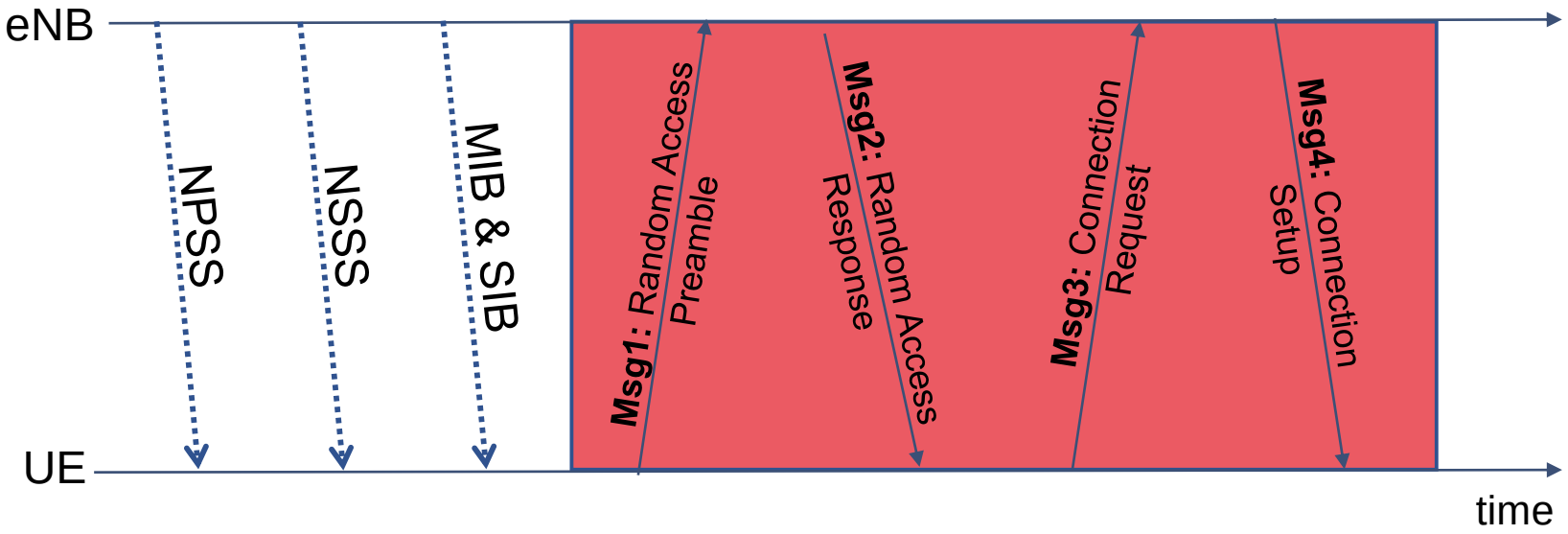
Low throughput

[1] Zhou Z, Accettura N, Prévost R, Berthou P. “Lightweight synchronization to NB-IoT enabled LEO Satellites through Doppler prediction.” IEEE WiMob 2023

[2] Zhou Z, Accettura N, and Berthou P. “A wake-up strategy enabling gnss-free nb-iot links to sparse leo satellite constellations,” IEEE Internet of Things Journal, vol. 12, no. 12, 2025.

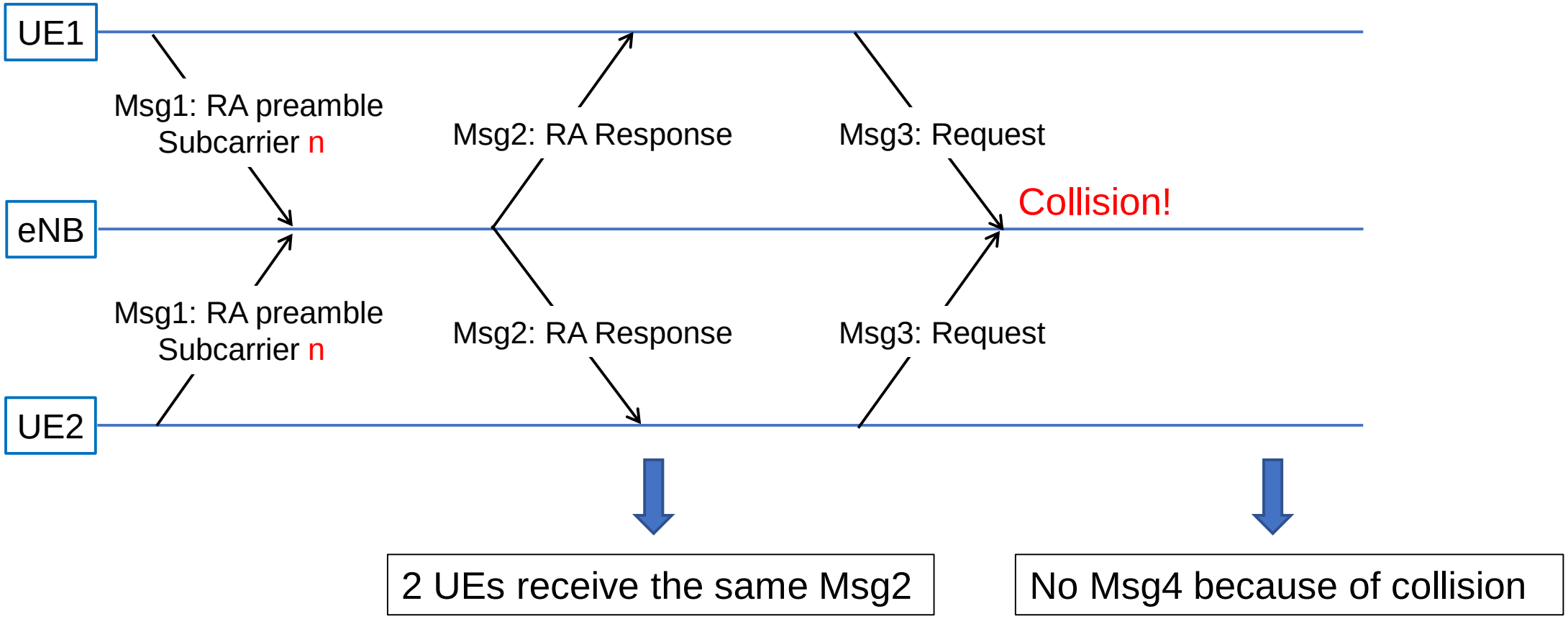
Research Problems





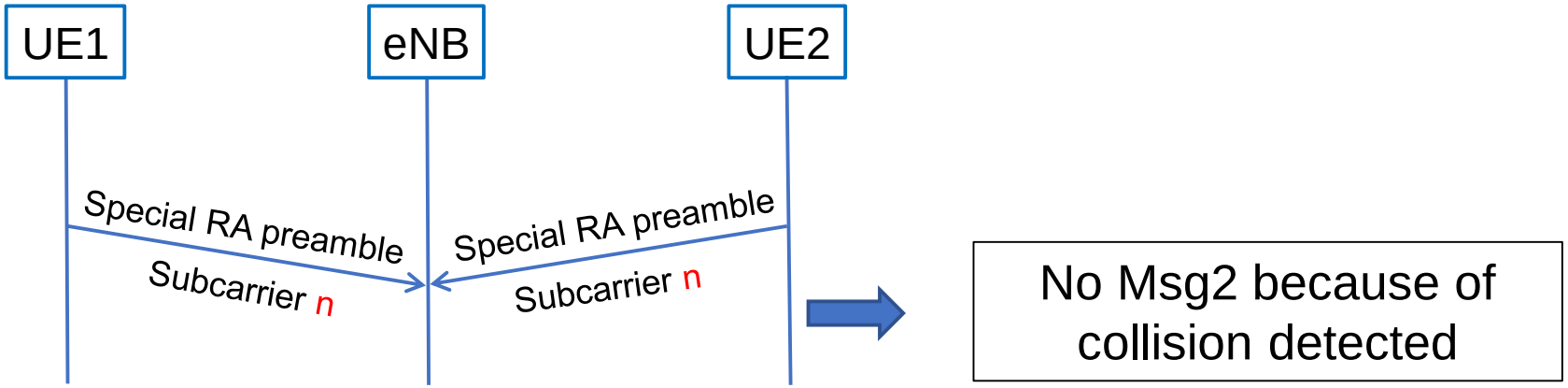
Random Access Procedure

Collision in Random Access procedure:



State of the art

Current literature solution [3]: **Avoid UEs sending Msg3**



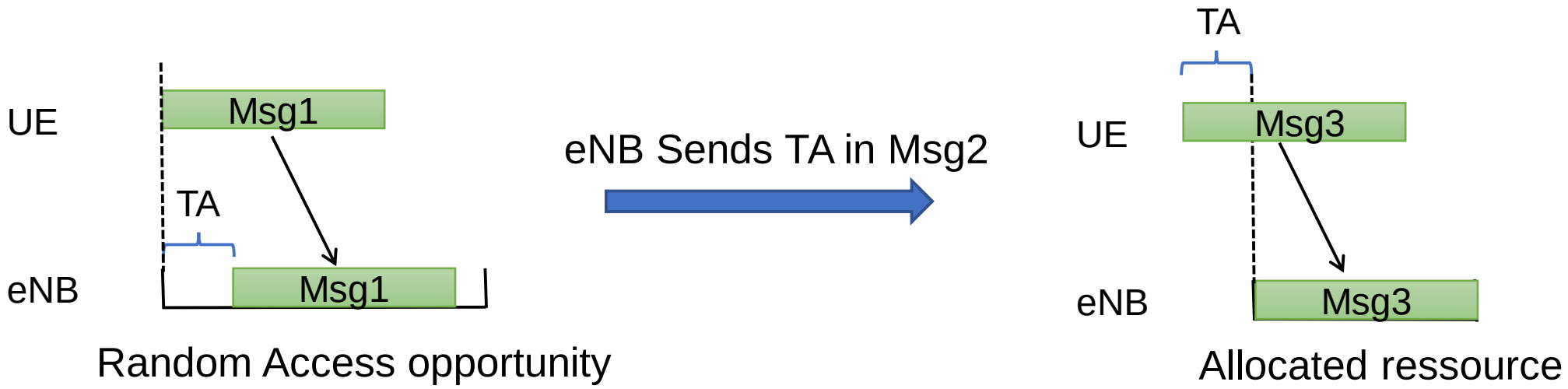
Throughput remains low in high-density device environments

Objective : Increase the probability of successful device access with minimal changes

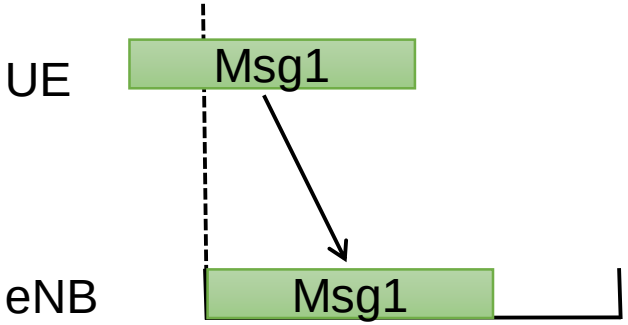
[3] Zhen, L., Zhang, Y., Yu, K., Kumar, N., Barnawi, A. and Xie, Y. Early Collision Detection for Massive Random Access in Satellite-Based Internet of Things. IEEE Transactions on Vehicular Technology, vol. 70, no. 5, 2021

How the current standard work

Timing Advance (TA) in Msg2 (Ground network)

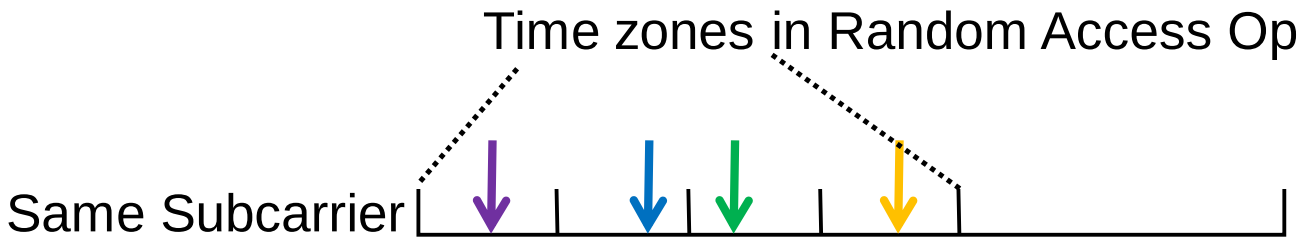


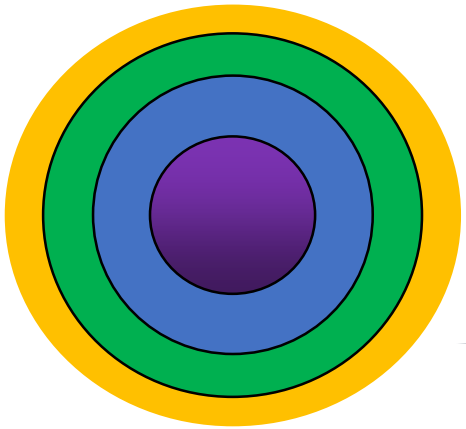
For satellite scenarios, TA is calculated before sending Msg1 (3GPP Release17)



Proposed Approach

Core idea [4]





Areas of equal size

UEs use TA in a different way

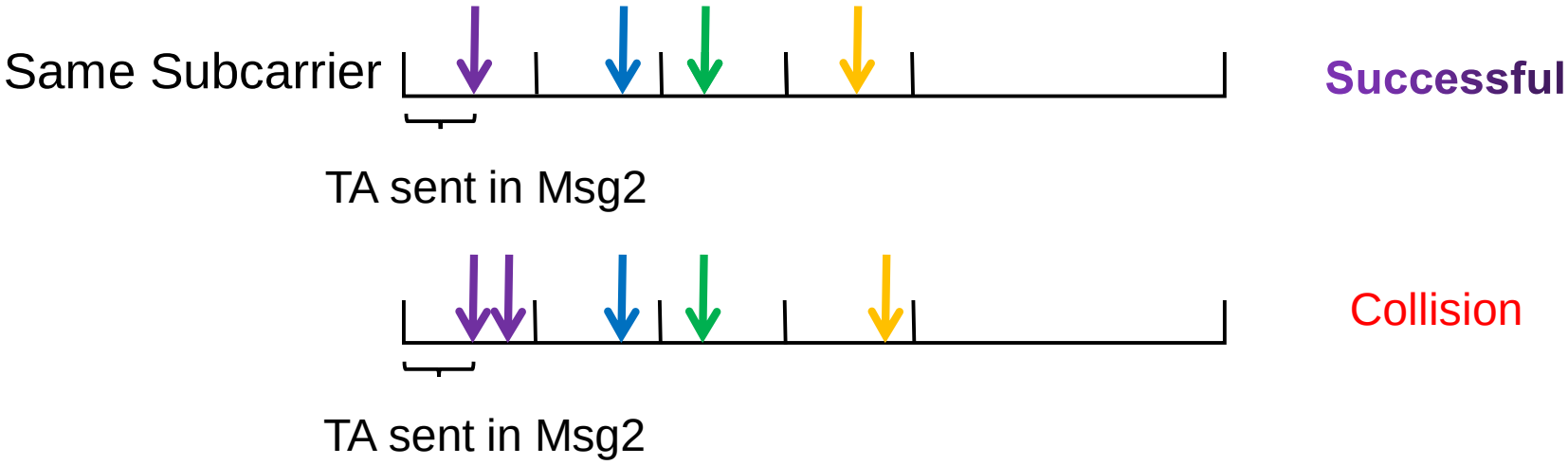
eNB sends TA in Msg2

Based on the value of TA and its own area (Time zone), UE decide to transmit Msg3 or not

[4] Z. Zhou, N. Accettura, and P. Berthou, "**Increasing the throughput of Direct-to-Satellite Narrowband IoT networks**", accepted at the IEEE Conference on Standards for Communications and Networking (CSCN),2025.

Proposed Approach 1

CFM (Closest First Method): No modification in modulation



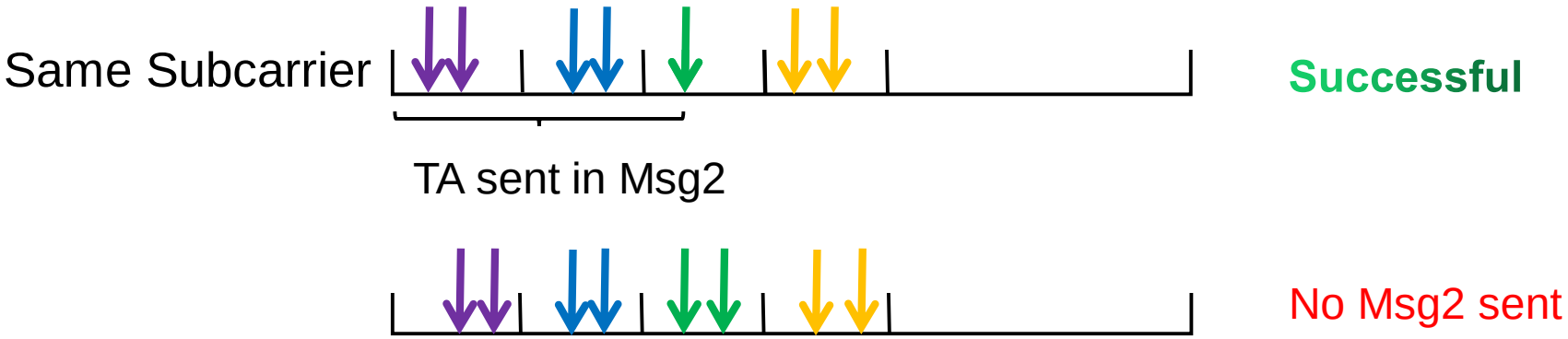
Average number of successful attempts:

$$N_C = \frac{\Gamma}{n_s} \sum_{i=1}^{n_s} e^{-\frac{i\Gamma}{mn_s}}$$

- Γ: Number of attempts
- m: Number of subcarriers
- n_s: Number of areas (time zones)

Proposed Approach 2

NFM (Non-collided First Method): Based on [3] -> Satellite can distinguish different preambles

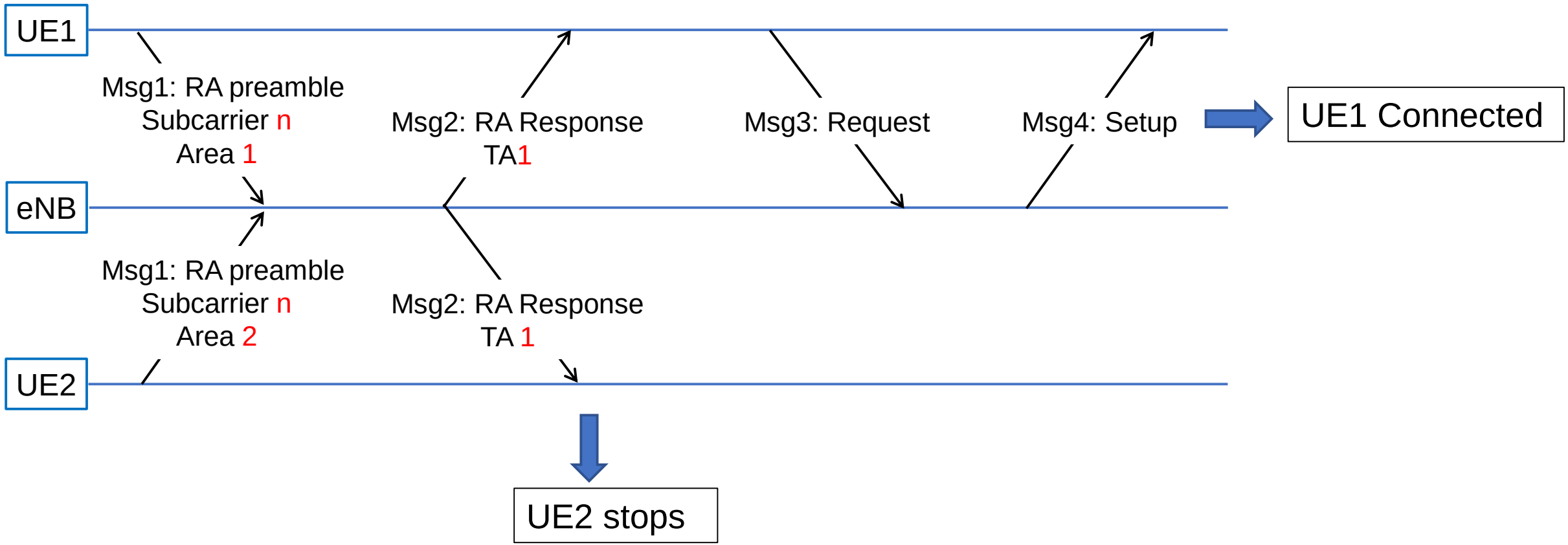


Average number of successful attempts:

$$N_N = m\left[1-\left(1-\frac{\Gamma}{mn_s}e^{-\frac{\Gamma}{mn_s}}\right)^{n_s}\right]$$

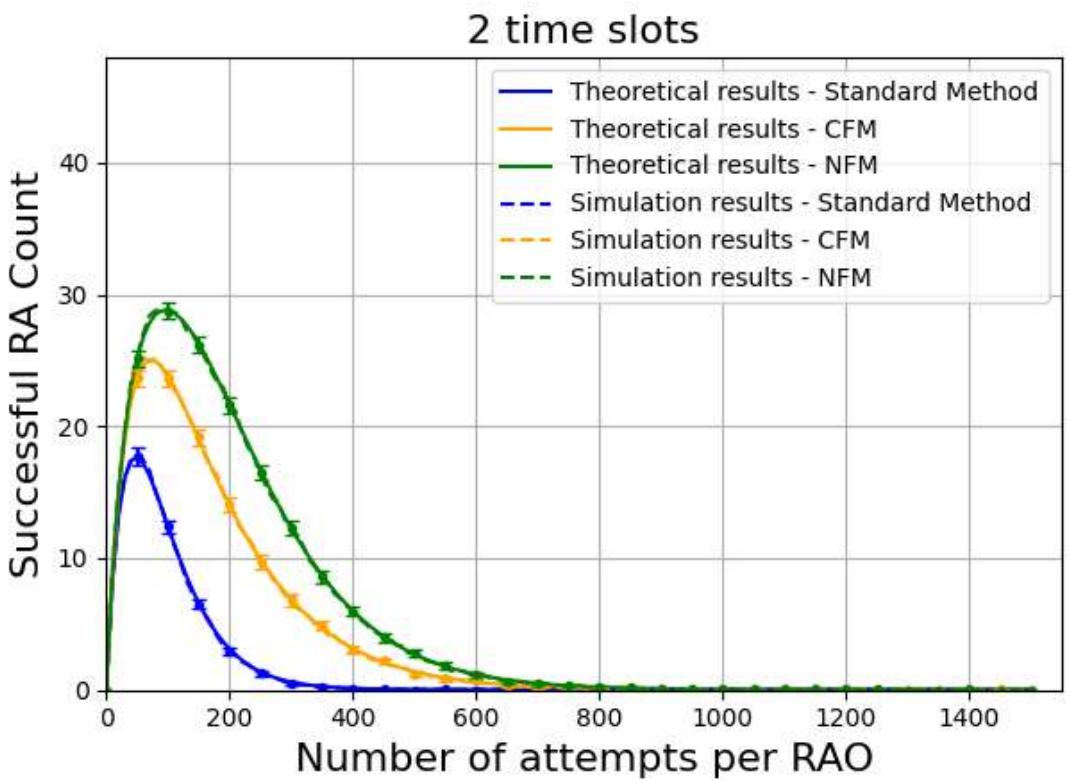
Outcome of the Proposed Approach

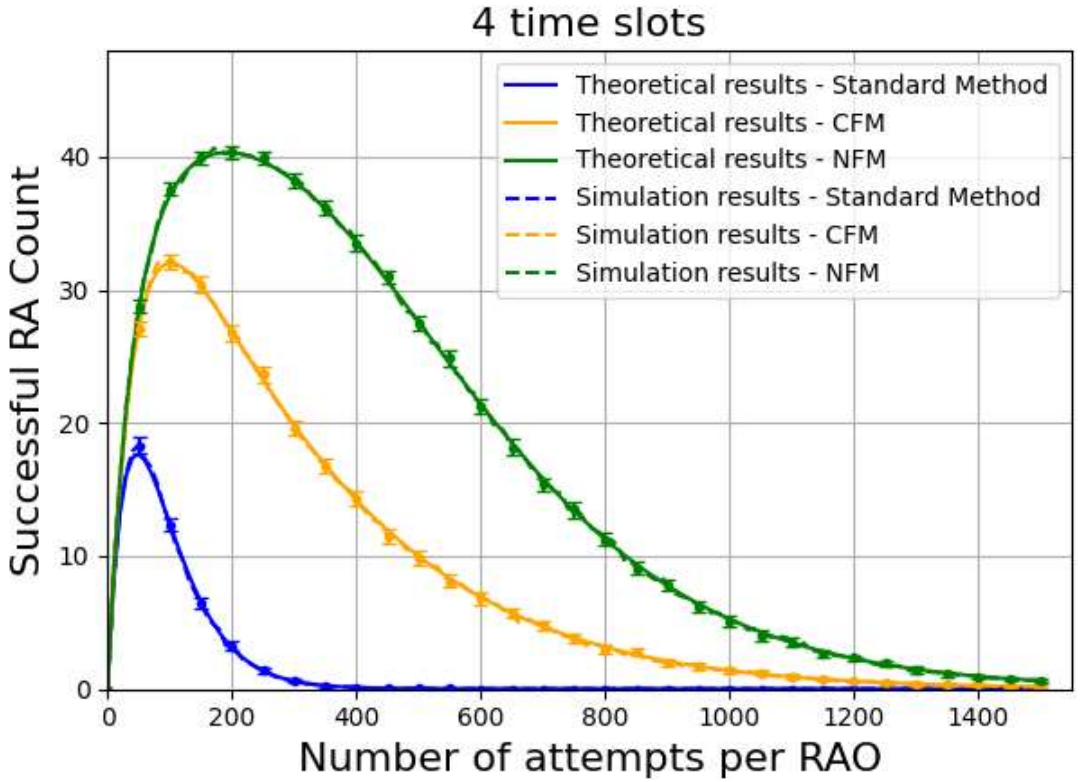
"**Collision**" with Proposed Approach:



Simulation results (Theoretical Validation)

Validation of the theoretical model through simulations (48 subcarriers)

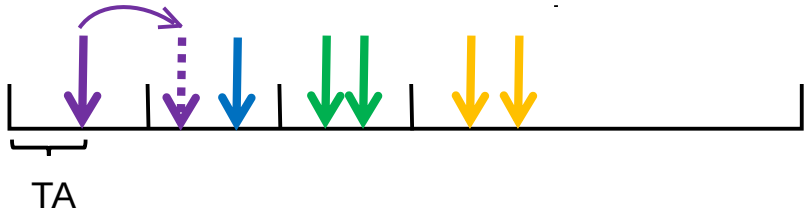




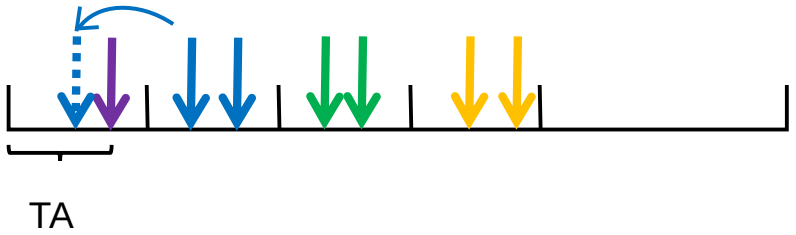
Situation without using GNSS

UEs cannot determine its position accurately, leading to the following situation:

- A UE may misjudge its area and fail to send Msg3

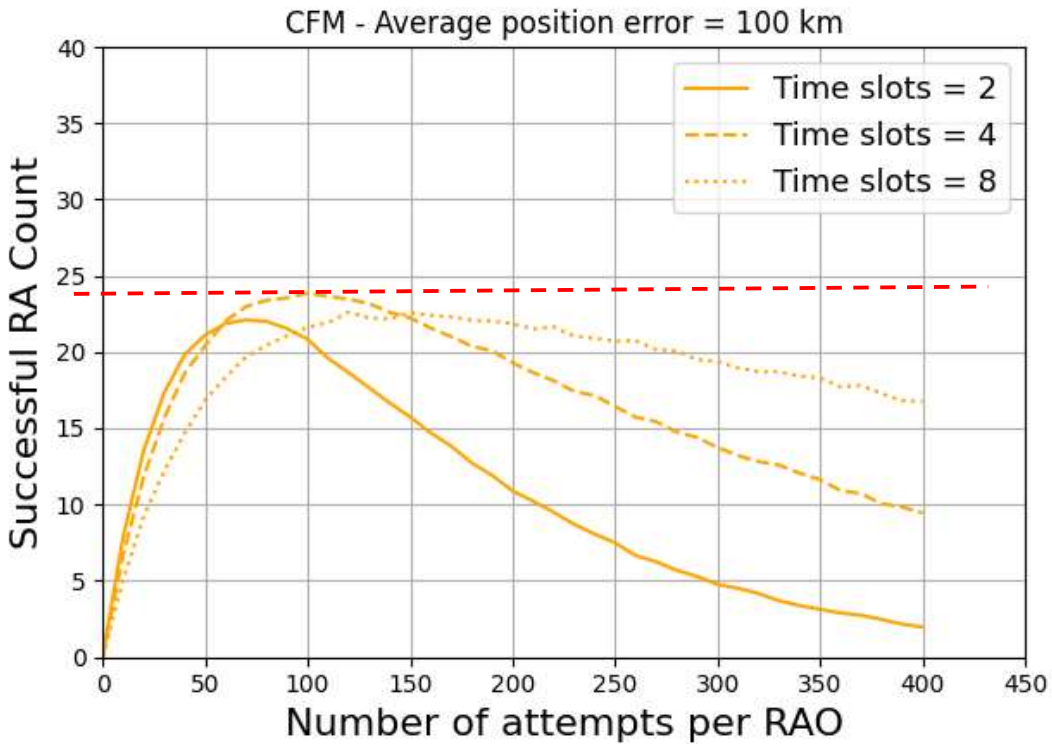


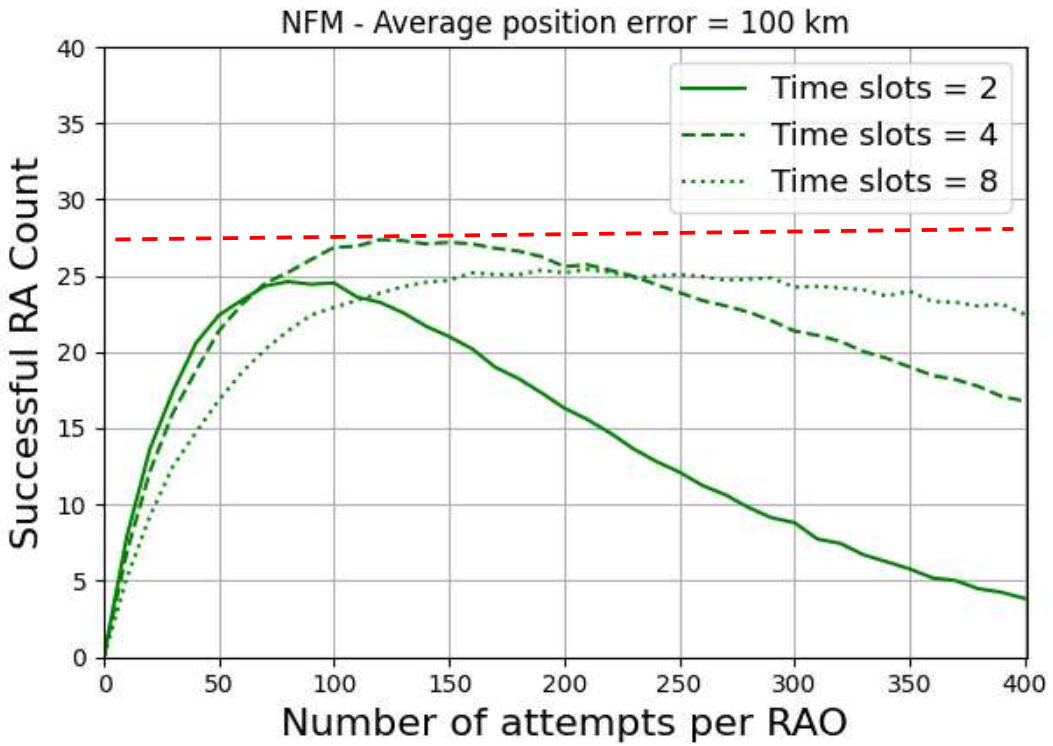
- Devices in other areas may cause **collisions** by thinking they are in the unique preamble area



Realistic simulation results

100 km of average position error





Fewer time slots may increase success rates by reducing the probability of UEs misjudging their area.

Conclusions

- The TA value in the 3GPP standard can be used for NTN scenarios to help increasing the throughput
- The simplest CFM method outperforms networks implementing the standard, at the cost of a firmware update
- The NFM method would further increase the throughput if satellites are able to distinguish overlapping preambles
- Future works
  - Non-uniform deployments
  - Optimization of resource allocations

Thank you for your attention !

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(Seeking postdoc opportunities)